OARDC'S COMPETITIVE
POSITIONING STRATEGY:

A DEVELOPMENT PATH FOR THE FUTURE

PREPARED FOR:
Ohio Agricultural Research & Development Center
The Ohio State University.

PREPARED BY:
Technology Partnership Practice
Battelle Memorial Institute

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The Business *of* Innovation

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Table of Contents

Table of Contents (continued)

Table of Contents (continued)

Page

List of Figures

Table of Contents (continued)

Page

List of Tables

Acronyms and Abbreviations

ATECH	Food and Agricultural Technology Commercialization and Economic Development Program
BL-3	Biosecurity Level-3
CAPPS	Center for Advanced Processing and Packaging Studies
CDC	Centers for Disease Control and Prevention
CIFT	Center for Innovative Food Technology
DNA	deoxyribonucleic acid
FAHRP	Food Animal Health Research Program
FDA	U.S. Food and Drug Administration
FY	Fiscal Year
IP	intellectual property
ISI	Institute for Scientific Information
nec	not elsewhere classified
NIH	National Institutes of Health
NSF	National Science Foundation
OAP	Ohio Aquaculture Program
OARDC	Ohio Agricultural Research and Development Center
OCAMM	Ohio Composting and Manure Management
OIE	World Organisation for Animal Health
OPGC	Ornamental Plant Germplasm Center
OSU	The Ohio State University
PCB	polychlorinated biphenyls
PCR	polymerase chain reaction
R&D	research and development
SARS	severe acute respiratory syndrome
SIC	Standard Industrial Classification
TGBP	Tomato Genetics and Breeding Program
TPP	Technology Partnership Practice
USDA	U.S. Department of Agriculture

Executive Summary

INTRODUCTION

The 21st century has opened to a salvo of predictions regarding the emergence of the "innovation economy," "knowledge economy," "biotech century," and other technology-based economic transformations. Despite the current hyperbole, it should be recognized that economic growth has always been sustained by innovation and the advancement of knowledge. In many respects, agriculture has been on the forefront in incorporating technological advances through the mechanization and now computerization of the industry and the introduction of new crops. It also is a leading innovator through advancements in areas as diverse as nutraceuticals, bioenergy, and biotechnology.

The knowledge economy is not, therefore, "new." As one pundit noted, "I have never seen a successful economy built on ignorance." Rather, technological and scientific innovation has increased in importance as a, ***if not the***, fundamental impetus of economic growth and competitiveness among developed nations.

Research and development (R&D) in the agricultural bioscience (agbioscience) field has been a consistent contributor to Ohio's innovation economy. Since its creation by the Ohio General Assembly in 1882, the Ohio Agricultural Research and Development Center (OARDC) has contributed a regular flow of applied R&D discoveries in the following diverse areas:

- Food processing and preservation technologies
- Processes for adding value to commodity crops
- New and improved crop cultivars with enhanced quality, yield, and disease/pest resistance characteristics
- Diagnostics, vaccines, and treatments for animal infectious diseases
- The application of genomics, post-genomic sciences, and biotechnology to the development of new tests, diagnostics, plant varieties, and novel products from biomass.

As a result of OARDC's critical research activities, the food and agricultural-related cluster in Ohio continues to be a key economic driver for the state. Analysis indicates that in 2000, the state's food and agricultural cluster generated approximately $80 billion in economic output, approximately 12 percent of the state's total output; added ten percent to Ohio's gross state product; and accounted for over one million Ohio jobs, which represents 15 percent of total state employment and 10 percent of total income.[1]

Therefore, the importance of continuing to provide critical technological advances to this large and robust sector of the state's economy can not be overlooked. The challenge for OARDC in the future is to strategically position itself to ensure that its investments in technological advancements have the greatest potential for positively impacting the economy of the State of Ohio.

[1] Sporleder, Thomas L. 2003. "OHFOOD: An Ohio Food Industries Input-Output Model – Version 6.0." The Ohio State University Department of Agricultural, Environmental, and Development Economics.

PURPOSE OF THE ASSESSMENT

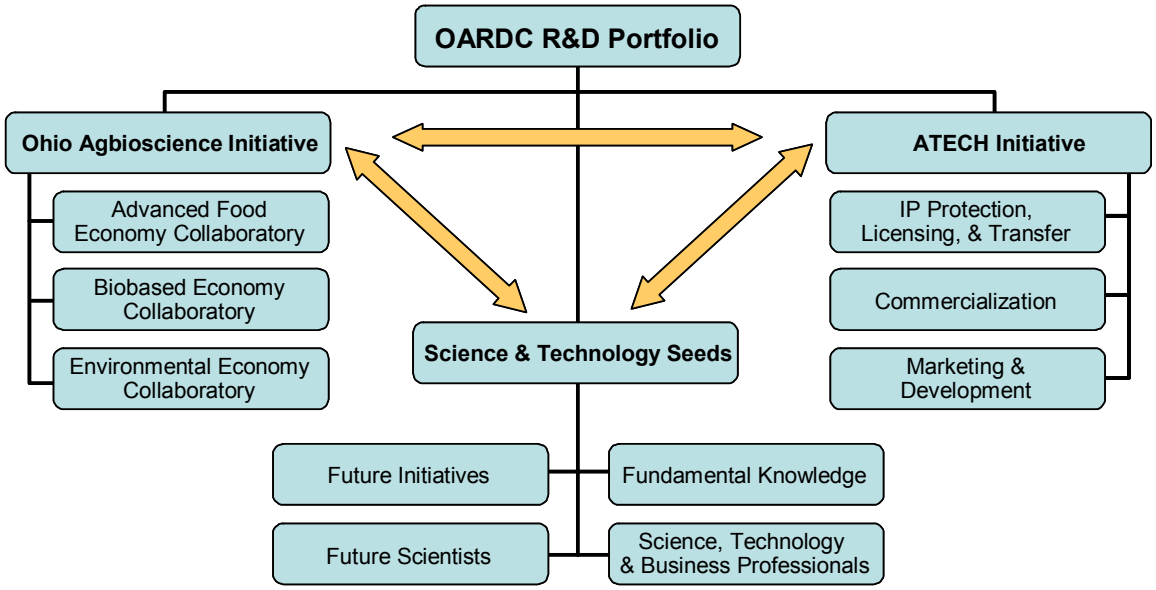
The recent report, *OARDC: A Generator of Positive Economic Impacts for Ohio* (Phase I of this two-phase effort), profiles the past, current, and likely future economic benefits accruing to the State of Ohio from the ongoing operations of OARDC. The examination found OARDC to be a substantial economic engine for the State of Ohio. The report highlights the legacy of agbioscience benefits and innovation in Ohio that has originated from OARDC functions and also areas of opportunity for increasing agbio-science benefits to the state.

While the impact report centers attention on some of OARDC's potential for significantly advancing Ohio's position in the agbiosciences, the purpose of this second phase is to understand OARDC's specific agbioscience technology platforms upon which to build substantial economic progress for Ohio. OARDC engaged Battelle's Technology Partnership Practice (TPP) to

- Identify the existing and emerging comparative advantages of OARDC and The Ohio State University (OSU) in the field of agbioscience.
- Highlight the key high-growth market sectors of the Ohio economy where OARDC could have the most positive impact.
- Profile the critical investment points that are likely to yield above average wages and job growth in Ohio from OARDC research.

This study reports the findings of research and strategic planning activities, targeting the three issues listed above. Specifically, the study identifies seven technology platforms in which OARDC has a demonstrable track record of R&D success and which show promise for future development. In addition, these seven platforms at a macro level indicate that three primary development pathways are suited to OARDC's expertise and the market needs of Ohio's agbioscience industry. It is within that conceptual framework that three Collaboratories are proposed, as diagrammed on the left-hand side of Figure ES-1.

Figure ES-1: OARDC R&D Portfolio



However, as this analysis unfolds, it is important to keep in mind that the Ohio Agbioscience Initiative is but one element of the triumvirate. It is critical that the OARDC balances its activities in the following three areas:

- Targeting initiatives to support the existing and emerging industrial base
- Promoting new innovative industrial technologies that promise continual economic growth, through its science and technology seed initiatives
- Commercializing, licensing, and marketing its technology through its ATECH Initiative.

THE AGBIOSCIENCE INDUSTRY IN OHIO: TRENDS AND DEVELOPMENTS

The inherent diversity of the agbioscience sector is a strong factor contributing to the growing industry focus. The cross-cutting technologies embedded in the agbiosciences have led many companies to pursue market opportunities in associated technologies, from bio-engineered foods and fuels to advanced new botanical medicines, from breeding healthier animals to genome mapping—each contributing to the advancement of life science activities, whether related to plant, animal, or human health discoveries and opportunities.

Furthermore, the agbioscience industry has a wide-ranging impact on industries not typically perceived to be linked with agbioscience technology. Industries are increasingly integrating new technologies in various ways to raise productivity and product capabilities. The innovative nature of the agbioscience industry has positioned it as a value-adding sector of the economy.

Definition of Ohio's Agbioscience Cluster

It is important to note that for the purpose of this study, the term "agbiosciences" will be narrower in focus than the more general food and agricultural-related cluster discussed earlier, which includes much of the agricultural commodity production and food service industries and represents 12 percent of the state's economy. This narrower definition will enable the analysis to focus solely on those industry sectors that are driving the agricultural technological advances within the state. Varying industrial classifications could be used to define the agbioscience sector of the economy. Currently, there is no commonly accepted definition of the industry. Categorization is difficult because of the diversity of agbioscience activity. The industry is dynamic and encompasses a wide variety of industrial application, and continual innovation further complicates the industry definition. Agbioscience advancements are constantly being applied in new and different ways, creating new industry sectors, such as genetically improved foods, or alternate energy sources, such as agriculturally based fuels. Figure ES-2 illustrates the eight major subsectors of agbioscience activity identified for this economic analysis.[2]

[2] Enclaves of economic activity may remain that are related to the biosciences but not included in this list. In part, this reflects the inadequacy of the current industrial classification code to categorize agbioscience activity. It also is symptomatic of the convergence precipitated by the diversity and expanse of the agbioscience sector.

The Agbioscience Sector in Aggregate

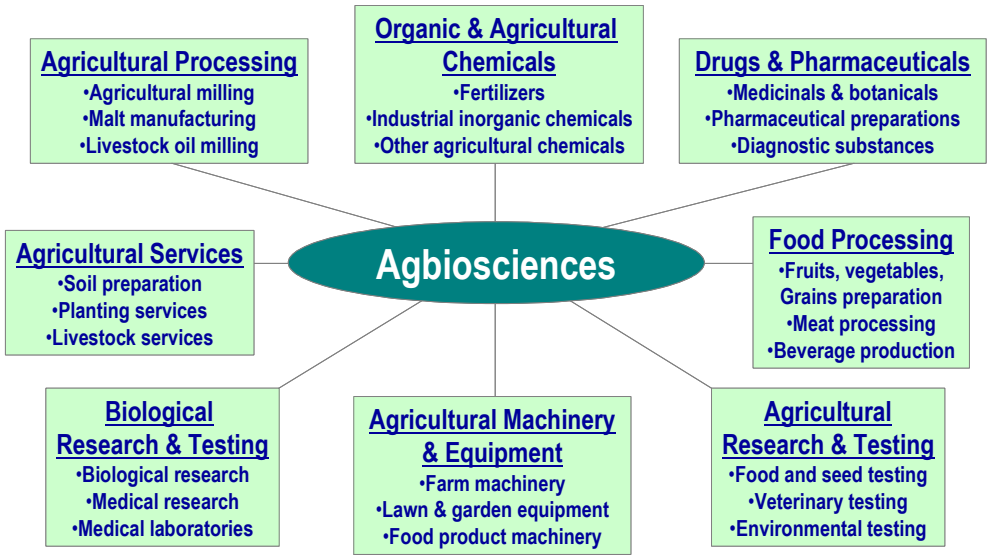
Examining the agbioscience industry in its entirety (i.e., the total combination of the eight subsectors) reveals a growing sector of the national economy. Between 1998 and 2003, establishments grew by 23 percent and employment by 8 percent across the nation. In 2003, almost 84,000 establishments were actively engaged in the agbioscience sector and accounted for employment of more than 2.8 million people.

In comparison, the number of agbioscience firms in Ohio is growing at an even faster pace than the nation. The establishment growth rate in Ohio between 1998 and 2003 was 27 percent, compared with the national establishment growth rate of 23 percent. However, employment growth in the Ohio agbioscience sector was below the national growth rate.

Key Facts:
State of Ohio Agbioscience Industry, 2003

- **2,839 establishments**
- **92,303 employees**
- **27% establishment growth, '98-'03, outpacing national growth of 23%**
- **2.5% employment growth, '98-'03, compared with 7.5% national growth**

Figure ES-2: Breakout of the Agbioscience Industry



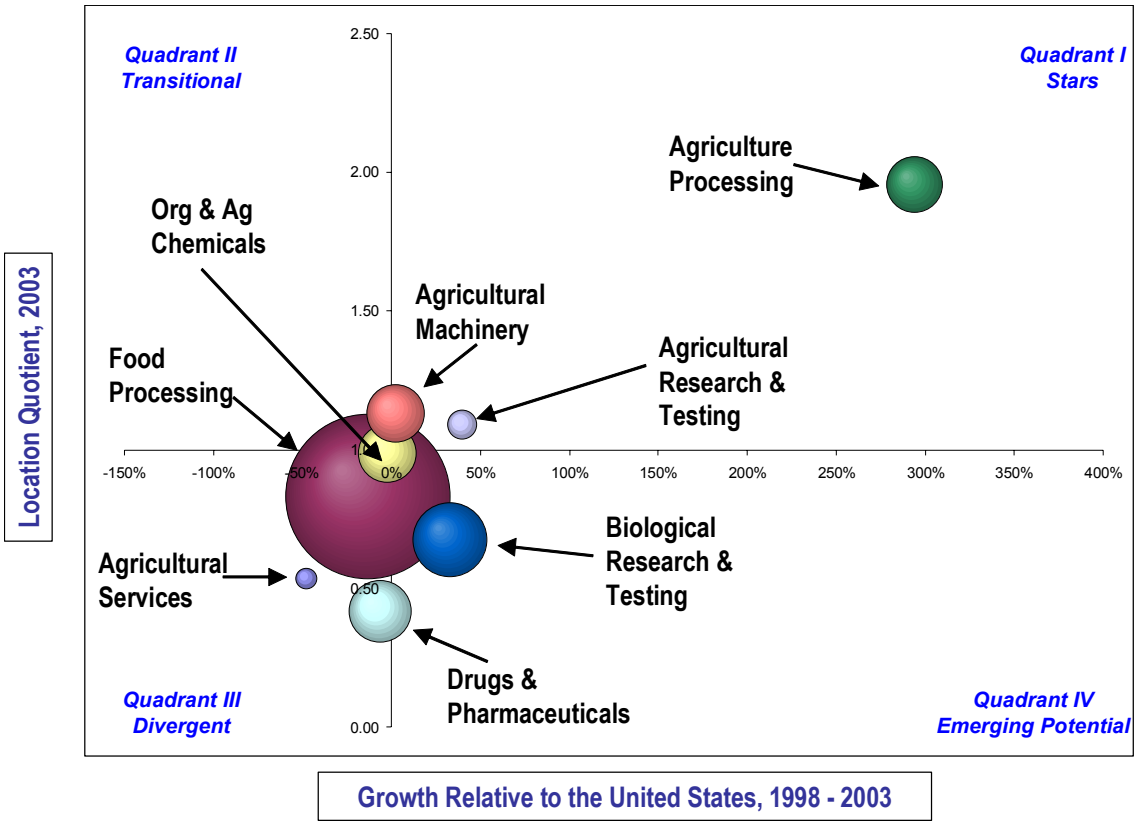
Ohio's Agbioscience Cluster Subsectors

The innovative nature of the agbioscience industry has positioned it as a value-adding sector of the economy. The innovative capacity is due, in part, to the wide range of industrial applications of the agbiosciences. Therefore, the diverse activity within the sector requires an analytical approach that examines individually the eight subsectors that compose the agbioscience industry to fully understand the complexity of the market.

In Figure ES-3, Ohio's agbioscience subsectors are categorized into four classes based upon their performance between 1998 and 2003. A subsector is assigned to a category based on its growth relative to U.S. growth and its location quotient. The four classifications of subsectors are stars, emerging potential, transitional, and divergent. Subsectors classified as stars or emerging are vital for the overall industry and its future development potential. These subsectors are often seen as the driving force behind the industry's

success. Subsectors classified as transitional or divergent are in a declining or evolving stage. Though not irreversible, these subsectors demonstrate performance below the national average and could threaten the long-term viability of the industry in Ohio.

Figure ES-3: Ohio Agbioscience Cluster Subsector Performance, 1998-2003



Note: Bubble size indicates the size of employment

NOTE: The large increase in Agricultural Processing jobs in Ohio between 1998 and 2003 is attributed to the relocation of a major operating unit of Procter and Gamble. According to the Onesource Corptech database, the operating unit of Norwich-Eaton Pharmaceuticals Inc., a subsidiary of P&G since 1982, was relocated to Cincinnati, Ohio, in November 1998. Dun & Bradstreet did not record this change until the subsequent year. Therefore, as a result of the relocation, approximately 5,000 jobs were added to the Agricultural Processing subsector, producing an overall growth rate of 287 percent within the subsector.

The following subsectors can be classified as "stars."

- ***Agricultural processing is the fastest-growing subsector in Ohio relative to the nation and is regionally specialized.*** Its growth in Ohio has positioned this subsector well above the national employment concentration level. The state's employment concentration in agricultural processing is almost twice the national average making agricultural processing in Ohio significantly specialized. In addition, Ohio's employment level represents an increasing concentration. The subsector's fast-paced growth is a major reason for the state's growing specialization.
- ***Agricultural research and testing is another fast-growing subsector in Ohio relative to the United States; although it is not considered to be regionally specialized, it is more concentrated in Ohio than in the nation.*** The strong growth in Ohio has led the subsector from a position of relative weakness (25 percent less concentrated than the nation) to a current employment level that is

9 percent more concentrated than the national employment level. In addition, the subsector's strong growth rate would indicate that this trend in its concentration level will continue. This is critically important to growing the technological strength of the state's agbioscience industry, because the majority of R&D occurs within this subsector. Ohio's agricultural research and testing "star" categorization bodes well for future growth and economic impact.

- ***Agricultural machinery, while hovering at the median, does show a positive growth rate and a greater concentration level relative to the nation.*** Between 1998 and 2003, the subsector had steady growth of 4.1 percent in Ohio, more than twice the national growth rate of 2.0 percent. Ohio is currently 13 percent more concentrated than the nation; however, this concentration level may be threatened if the employment growth rate does not maintain pace with the nation.

The "emerging potential" subsector is as follows:

- ***Biological research and testing is the second fastest-growing agbioscience subsector and outpaced growth of this industry at the national level.*** The positive growth rate and concentration level increase are positive signs for future economic impact because the biological research and testing subsector, much like the agricultural research and testing subsector, provides the building blocks for the future growth of other agbioscience subsectors.

The subsectors that can be classified as "divergent" are listed below.

- ***The drugs and pharmaceuticals subsector is growing but at a rate below the national average.*** Furthermore, the concentration of the subsector in Ohio, which was approximately 60 percent less than in the nation, actually declined by 1 percent between 1998 and 2003. Therefore, although the subsector is growing in Ohio, it is not keeping pace with national growth trends and, therefore, is losing relative concentration.
- ***Food processing is the largest subsector in terms of employment, by far, but is in a state of decline.*** Between 1998 and 2003, the subsector lost 12 percent of its employment base. This decline is significant in light of the 1.5 percent positive growth demonstrated at the national level. The decline in Ohio employment represented a loss of approximately 7,250 jobs, leaving the food processing subsector employing 52,750 individuals across 1,142 establishments in 2003.
- ***The organic and agricultural chemicals subsector is approximately as concentrated in Ohio as in the nation; however, it is experiencing employment decline.*** The concentration level varied by only 1 percent over the time period, leaving the organic and agricultural chemicals subsector only 1 percent less concentrated than the nation. But, if this employment decline continues, the concentration level can be expected to decline over time.
- ***Agricultural services experienced the largest decrease in terms of employment and is well below the national concentration average.*** This fast-paced decline is in sharp contrast to the positive growth demonstrated at the national level. In addition, the subsector is the smallest in terms of employment base among the eight agbioscience subsectors.

To create a more durable and vibrant agbioscience industry, OSU through OARDC must target initiatives to support existing strengths and encourage and stimulate emerging subsectors. While OARDC must concentrate on tailoring initiatives to target those niches with the greatest promise of economic growth, it must not lose sight of the inherent diversity of agbioscience activity. ***The challenges that face leaders are the needs to balance initiatives between solidifying core areas within the agbiosciences and to promote new innovative industrial technologies that promise continual economic growth (see Figure ES-1).***

AGBIOSCIENCE CORE COMPETENCY ASSESSMENT

This section examines the agbioscience research core competencies that will drive future economic growth. One of the requirements for understanding the potential for agbioscience development is a solid understanding of the existing agbioscience-related research competencies within OSU, and specifically OARDC, upon which future agbioscience advances may be made. Across the nation, each state's major agricultural research institutions have their own particular core research strengths and focus areas, and, as will be shown, Ohio is no exception.

In terms of total university-based R&D activity, OSU stands 19th in the nation, with $390.7 million in total research funding (as recorded by the National Science Foundation [NSF] for 2001). This level of R&D at OSU outpaces all other universities within the State of Ohio.

Furthermore, OSU has historically performed relatively well in terms of academic life science R&D. In 2001, 50.5 percent ($197.4 million) of the $390.7 million in total OSU-based research was within the life sciences—this $197.4 million research performance placed OSU 29th in the nation. It also is interesting to note that OSU has sustained a strong position in multiple areas of life science R&D, with a ranking of

- 27th in the nation in "agricultural sciences" ($40.8 million)
- 32nd in "biological sciences" ($58.4 million)
- 12th in "other life sciences" ($16.8 million).

It is important to note two additional items. First, for the purposes of this agbioscience analysis, it must be pointed out that OSU accounts for 99.1 percent of all of agricultural sciences research conducted in the State of Ohio. This is obviously due in large part to OSU's designation as the state's land grant institution; however, in other areas of life science research, OSU is capturing only approximately one-third of the total funding to the state. Secondly, in two additional areas important to the agbioscience research base, chemical engineering and chemistry, OSU ranks 17th and 19th in the nation, respectively. This indicates that OSU's core basic science research base upon which its agbioscience research is conducted is equally strong.

Key data relating to OSU's recent performance in the agricultural sciences are highlighted in Table ES-1.

Table ES-1: Recent Agricultural Science Performance

Metric	Ohio State University	Ohio Total	United States
Total Academic R&D, FY 2001	$390,652,000	$995,972,000	$32,723,078,000
Total Agricultural Sciences R&D, FY 2001	$40,794,000	$41,150,000	$2,318,081,000
Agricultural Sciences as a % of Total Academic R&D	10.4%	4.1%	7.1%
Academic Agricultural Sciences R&D Per Capita, FY 2001	N/A	$3.61	$8.12
USDA Obligations for S&E R&D, FY 2001	$28,167,000	$31,724,000	$1,199,187,000
USDA as a % of Total Federal Obligations for S&E R&D, FY 2001	15.6%	5.1%	5.3%
% Increase in Academic Agricultural Sciences R&D, FY'97-01	-14.1%	-13.4%	17.9%

Sources: National Science Foundation, Survey of Research and Development Expenditures at Universities and Colleges, *and Battelle calculations, FY 2001; United States Census Bureau Estimates, FY 2002.*

The data show that OSU has a greater concentration of its total academic R&D in the agricultural sciences than Ohio or the nation. However, the data also illustrate that, while OSU's percentage share of agricultural research is above the norm for both Ohio and the nation, OSU and Ohio are not keeping pace in

growing their agricultural science research base. OSU does have a larger percentage of U.S. Department of Agriculture (USDA) funding as a percentage of total federal obligations, 15.6 percent versus 5.3 percent, respectively. However, the agricultural science academic R&D spending per capita in Ohio is considerably below the U.S. average ($3.61 versus $8.12). In addition, OSU's comparative concentration in the agricultural sciences will decline if OSU's growth in R&D funding does not keep pace with the growth rate of the nation. Analysis of the Institute for Scientific Information (ISI) citations data also highlighted key research strengths at OARDC. In agbioscience-specific fields, OSU displays its national leadership in agricultural research endeavors by ranking in the top ten in terms of its citation intensity when compared to all other U.S. academic institutions.

The analysis of USDA, NSF, ISI, and other published data help set the context for understanding where OARDC/OSU's core competencies in agbioscience research are focused. To further investigate these fields and deepen our understanding of the core agbioscience focus areas at OSU, extensive interviews were conducted with administrators, faculty, and staff at OARDC and the University. After performing the qualitative interview, conclusions were drawn regarding the agbioscience core competencies indicated as present at OARDC and OSU by the interviews and data. The quantitative and qualitative evaluation of OARDC's strengths and core competencies are summarized below.

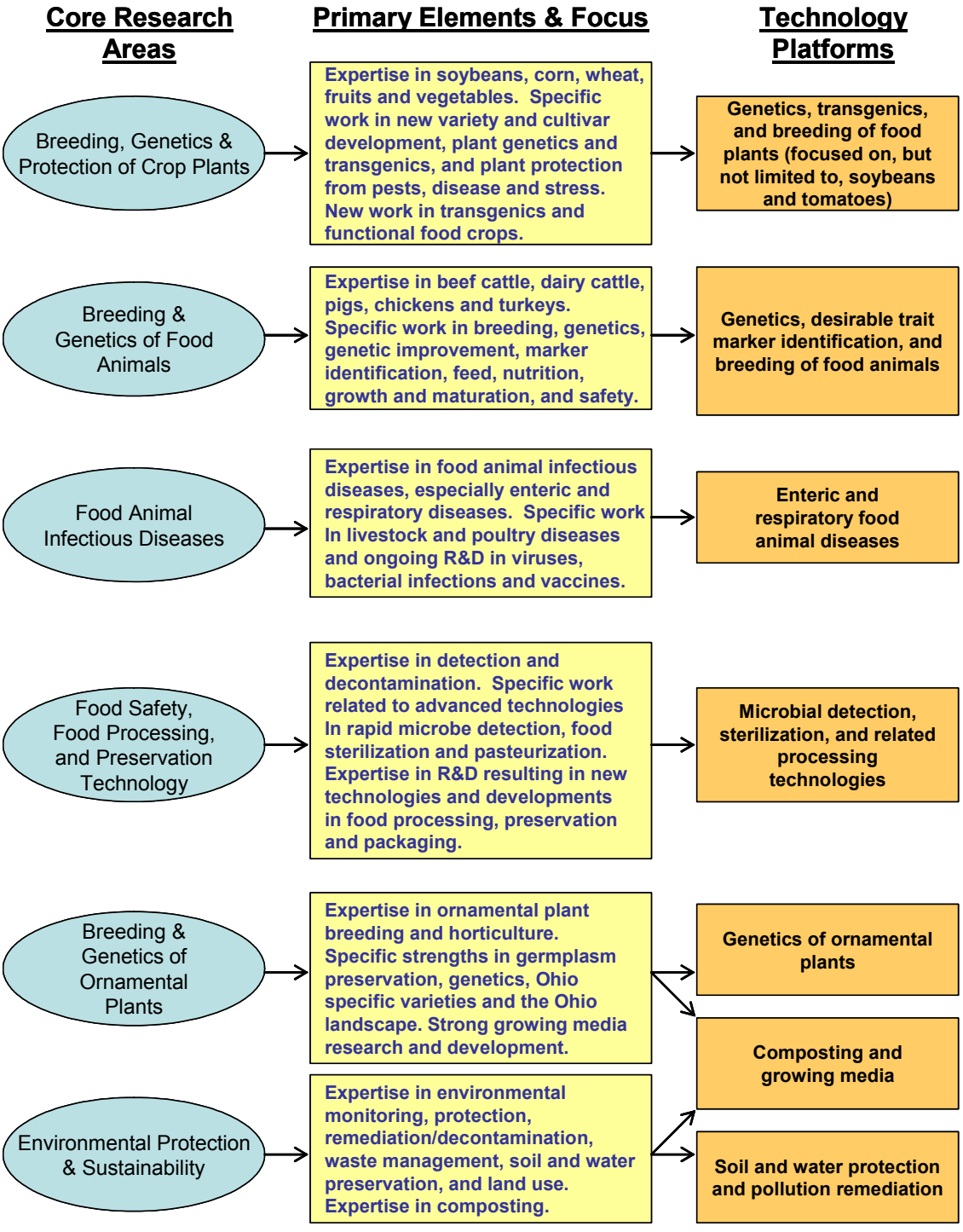
CORE TECHNOLOGY PLATFORMS UPON WHICH TO BUILD OHIO'S AGBIOSCIENCE DEVELOPMENT

In an organization with the broad size and scope of OARDC, a wide range of fields in which R&D excel may be observed. The goal of this analysis is to identify the strongest technology platforms upon which agbioscience economic development may be based. Figure ES-4 illustrates the primary areas in which OARDC has demonstrable expertise and the R&D being conducted within them. The main core competencies are drawn from these areas of R&D focus and represent the R&D "hubs" from which significant future progress may be expected. **Seven technology platforms at OARDC have significant merit as platforms for future progress, including:**

- ***Genetics, transgenics, and breeding of food plants (focus on, but not limited to, soybeans and tomatoes)***
- ***Genetics, trait marker identification, and associated breeding of food animals***
- ***Enteric and respiratory food animal diseases, including zoonotic diseases***
- ***Food decontamination, sterilization, and associated processing technologies***
- ***Ornamental plant genetics and germplasm "mining" for functional genes useful in the agbiosciences***
- ***Environmental protection and decontamination technologies focused on soil and water***
- ***Composting and advanced potting soil/growing media development.***

These technology platforms represent core competencies in which OARDC has a demonstrable track record of R&D success and which show promise for future development. Selecting these seven does not mean that OARDC has no other areas of competency, but rather that other areas are smaller or more embryonic in their development and currently form less of a launch platform.

Figure ES-4: OARDC's Core Competencies



The platforms and recommended focus areas identified present multiple potential development opportunities for Ohio. They do, however, vary in the potential size of their impacts, the scope of the economic sector in Ohio that may be built upon each platform, and the time required to realize such potential development. To assist OARDC in its economic development promotion decisions, a perspective on the prioritization of these opportunities is required.

Table ES-2 summarizes key recommendations from the examination of each potential platform.

Table ES-2: Key Recommendations for Technology Platforms

Technology Platform	Recommendation/ Conclusion	Market Analysis
Genetics, transgenics, and breeding of food plants (focused on, but not limited to, soybeans and tomoatoes)	OARDC research should focus on the following: • Enhancing the functional food, phytochemical, and nutraceutical components of soybeans. • Establishing the health benefits of soybean phytochemicals and then increasing the expression of these beneficial chemicals in Ohio varieties. Represents opportunity to significantly increase the value of the Ohio crop and engender the development of the functional food and nutraceutical sectors in the state. • Extracting relevant nutrients and phytochemicals (or maintaining their active expression after food processing). • Continuing OARDC's ongoing work in disease and stress resistance and yield enhancement. • Pursuing tomato-based research along the same lines as that of soybeans. Could reap economic rewards for the state, but at a lower overall volume than realized by soybeans.	Large monetary opportunity given rapid growth of worldwide functional food and nutraceutical sectors. Critically important to increasing value and productivity of the key crop on Ohio farms—soybeans.
Genetics, trait marker identification, and associated breeding of food animals	In the near term, applied food animal sciences at OARDC/OSU should focus on two principal areas: • Marker and gene identification and the production and marketing of diagnostic tests • Production of value-added animal breeds, via transgenics or traditional pathways, for the Ohio livestock and poultry system. Animal transgenics for biomedical purposes has a long-term development horizon; but, discussions related to interest in the field should be opened up between the OSU College of Medicine and Public Health, the College of Pharmacy (for animal biopharming), and OARDC animal sciences.	Large monetary opportunity for advanced marker technologies and diagnostic tests for food animals. Opportunities to leverage OARDC genetics and transgenics skills for early entry into value-added animal production and transgenic animals. Opportunity to link transgenic animal expertise to OSU human medical research.

Table ES-2: Key Recommendations for Technology Platforms (continued)

Technology Platform	Recommendation/ Conclusion	Market Analysis
Enteric and respiratory food animal diseases, including zoonotic diseases	A clear near-term focus of OARDC should be R&D leading to the following: • Commercializable diagnostic tools, tests, vaccines, drugs, and biologics related to established and emerging food animal diseases. • Major categories of disease, including enteric, respiratory, and immunosuppressive diseases and disorders. OARDC has been wise in focusing its research on these areas and this approach should be continued. Approaches to zoonotic diseases may benefit from liaison and multidisciplinary research projects between OARDC and human medicine researchers on the Columbus campus.	Direct opportunity to continue OARDC IP generation and commercialization related to diagnostic tools, tests, vaccines, drugs, and biologics. Near-term opportunities to link clear OARDC skills in this area to large volume of funds being provided at the federal level for biosecurity and agrosecurity.
Food decontamination, sterilization, and associated processing technologies	• The current focus of the CAPPS program is on point and pragmatically led in partnership with industry—this is the type of model initiative that should be duplicated elsewhere within the OSU system. • A focus on advanced sterilization and decontamination technologies and associated devices based on the work at the Columbus labs should remain a high priority for the University. • In addition, the rapid microbe detection technologies being developed by OARDC faculty have potential not only in food safety, but in biosecurity applications where monitoring for bio-contaminants will be a key growth sector.	Significant opportunity for R&D discoveries leading to an expanded decontam-ination and sterilization equipment advanced manufacturing sector in Ohio. Opportunity to open biotechnology opportunities in microbe and contaminant detection (again with significant biosecurity funding possibilities).
Ornamental plant genetics and germplasm "mining" for functional genes useful in the agbiosciences	• Applied R&D and extension services to the rapidly growing nursery and horticulture sector in Ohio should be an OARDC economic development priority. • Gaining *technology-based* economic development from this strength area will require a formal program to structure ornamental genomics research that links to biotechnology, pharmacology, and other plant and medical bioscience initiatives that may result in novel and valuable compounds and resources from plant germplasm.	Enhancing Ohio's position in the lucrative ornamental plants/nursery business sector. Potential for very large economic returns on novel gene/compound discoveries useful to medicine within unique ornamental plant germplasm resources of OSU.

Table ES-2: Key Recommendations for Technology Platforms (continued)

Technology Platform	Recommendation/ Conclusion	Market Analysis
Environmental protection and decontamination technologies focused on soil and water	• Development of rapid diagnostic tests to check for pollutants/contaminants in water resources and Ohio's agricultural soils is recommended. • The development of microbes and microorganisms for pollution control and decontamination applications also is a logical economic pursuit.	Large worldwide market for environmental protection and remediation technologies. Near-term federal financing opportunities due to relationship to biosecurity and homeland security.
Composting and advanced potting soil/growing media development	• Work should continue on increasing the quality of growing media while reducing its production costs. This may include R&D related to developing new technologies for producing and managing advanced growing media products, and potentially using various municipal waste, agricultural waste, and other waste streams in the industry. • Continued OARDC work on probiotic and biocontrol inoculants shows considerable promise for potential "agbiotechnology" chemicals and products.	Potentially significant ag-chemicals market if biocontrol inoculants research at OARDC is successful. Long-term opportunities to reduce disposal and environmental costs of waste streams and gain value from them through advanced composting technologies.

Each platform presents opportunities for technology-based agbioscience economic development in Ohio. It is important to note that several of the platforms can be further enhanced by developing research partnerships between the OSU College of Medicine, College of Engineering, and College of Food, Agricultural, and Environmental Sciences. Interdisciplinary research has been a focus of OARDC for a number of years. For instance, OARDC staff has recently participated in a series of discussions regarding potential projects related to biomass processing with their peers within the College of Engineering. However, for Ohio to truly benefit from the wide array of research being undertaken within OSU, the institution's leadership must promote and provide support for more robust translational/interdisciplinary partnerships that transcend the traditional academic boundaries.

The following analysis estimates which platforms may provide the best near-term opportunities for significant agbioscience-led economic development in the state.

Suggested Platform Prioritization

High-Impact, Near-Term Opportunity Areas: These platforms have substantial market opportunities, and significant economic development potential for Ohio within a time horizon of the next 5 years.

Table ES-3: Technology Platforms with High-Impact, Near-Term Opportunities

Technology Platform	Near-Term Development Component
Genetics, transgenics, and breeding of food plants (focused on, but not limited to, soybeans and tomatoes)	Expression of phytochemical, functional food, and nutraceutical characteristics in soybeans to add product value.
Genetics, trait marker identification, and associated breeding of food animals	Identification of useful/valuable trait markers and development of associated diagnostic tests, tools, and services.
Enteric and respiratory food animal diseases, including zoonotic diseases	Development of commercializable diagnostic tools, tests, vaccines, drugs, and biologics related to established and emerging food animal respiratory and enteric diseases. Development of commercializable diagnostic tools, tests, vaccines, drugs, and biologics related to zoonotic respiratory and enteric diseases. Relate work to biosecurity and agrosecurity to attract federal biosecurity funds (in addition to USDA, CDC, and NIH funding).
Food decontamination, sterilization and associated processing technologies	Development of rapid microbe and contaminant detection technologies for deployment in food safety and biosecurity applications. Applied R&D to bring commercialization from advanced technologies in pulsed electrical fields, ohmic heating, and high-pressure sterilization.

High-Impact, Long-Term Opportunity Areas: These platforms have substantial market opportunities, but the time horizon for realizing successful economic development in Ohio will likely exceed five years.

Table ES-4: Technology Platforms with High-Impact, Long-Term Opportunities

Technology Platform	Long-Term Development Component
Genetics, transgenics, and breeding of food plants (focused on, but not limited to, soybeans and tomatoes)	Development of soybeans optimized for bio-industrial chemical applications, such as biofuels, etc. Development of chemical extraction and preservation technologies for maintaining functional food characteristics.
Genetics, trait marker identification, and associated breeding of food animals	Development of transgenic animal varieties with enhanced characteristics of market value. Connection of animal transgenics to human biomedical research and production of organs/systems for xenotransplantation. Biopharming via animal production pathways.
Food decontamination, sterilization and associated processing technologies	Development of an enhanced sterilization and decontamination sector in Ohio, built on new OARDC technologies. Development of food processing applications for pulsed electric fields and other advanced technologies.
Ornamental plant genetics and germplasm mining for functional genes useful in the agbiosciences	Discovery and development of biomedical and biotechnology applications for novel genes and compounds from ornamental plant germplasm resources.

Table ES-4: Technology Platforms with High-Impact, Long-Term Opportunities (continued)

Technology Platform	Long-Term Development Component
Environmental protection and decontamination technologies focused on soil and water	Development of microbes and other technologies for the digestion and remediation of soil and water contaminants.
Composting and advanced potting soil/growing media development	Discovery and development of bio-inoculants for enhancing the biological health of plant-growing media.

Lower Impact, Near-Term Opportunity Areas: These platforms have market opportunities and economic development potential for Ohio within a five-year time horizon.

Table ES-5: Technology Platforms with Lower Impact, Near-Term Opportunities

Platform	Near-Term Development Component
Genetics, transgenics, and breeding of food plants (focused on, but not limited to, soybeans and tomatoes)	General improvement of yield, quality, disease resistance, and associated "traditional" qualities of soybeans suited for the Ohio growing environment. Expression of phytochemical, functional food, and nutraceutical characteristics in tomatoes to add product value.
Environmental protection and decontamination technologies focused on soil and water	Accessing biosecurity funding to further develop OARDC/OSU R&D in soil and water monitoring and protection.
Ornamental plant genetics and germplasm mining for functional genes useful in the agbiosciences	Continued work to expand and enhance Ohio's nursery and landscape business sector.

Lower Impact, Long-Term Opportunity Areas: This platform has market opportunities but the time horizon for realizing successful economic development in Ohio will likely exceed five years.

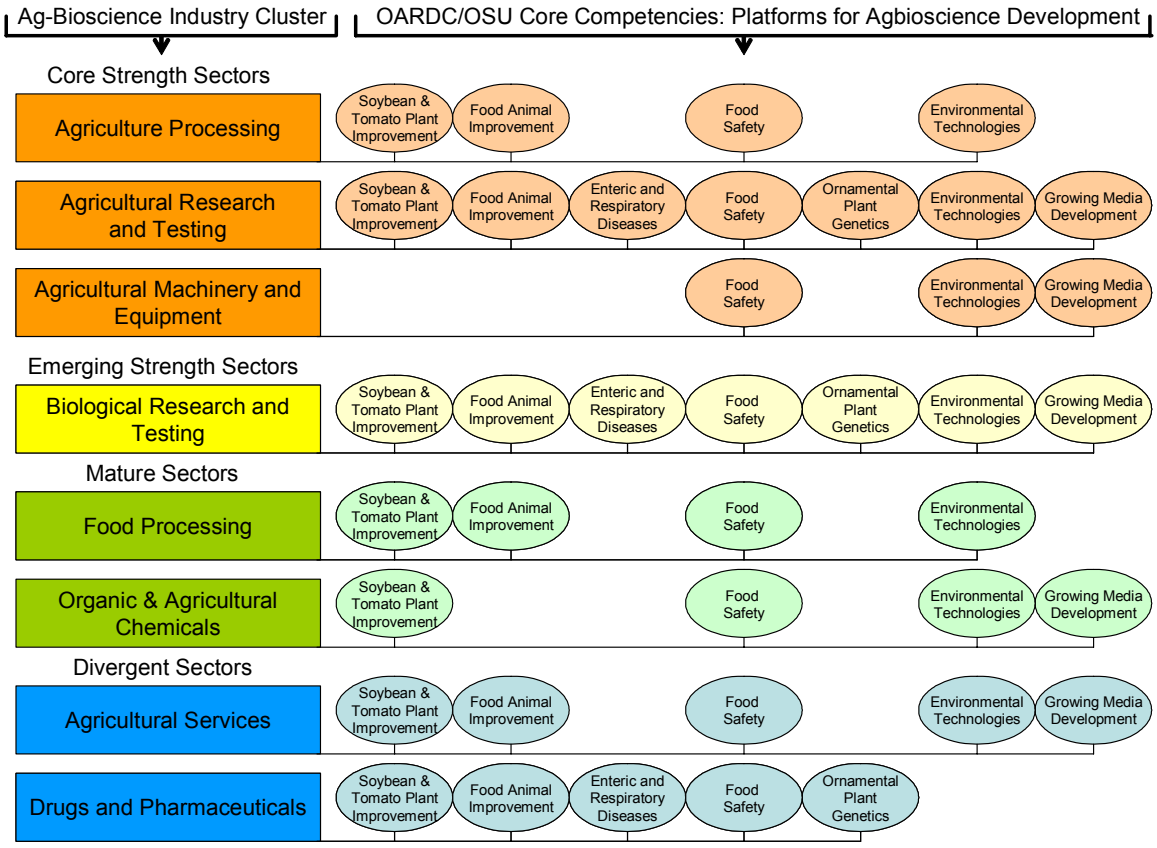
Table ES-6: Technology Platform with Lower Impact, Long-Term Opportunities

Platform	Long-Term Development Component
Composting and advanced potting soil/growing media development	Reduce disposal and environmental costs of waste streams, and gain value from them through advanced composting technologies and associated biomass conversion research.

Agbioscience is a clear target of opportunity for Ohio

Agriculture and agbioscience-related sectors in Ohio are important contributors to the Ohio economy. The dramatic changes being facilitated in the agbiosciences by genomic discoveries, transgenics, and other leading-edge advancements are bringing with them the potential to leverage Ohio's agbioscience strengths for technology-industry growth in the state. OARDC is well positioned to build upon its key strengths and leverage them for agbioscience economic development along a platform model.

Figure ES-5: Linkages between Agbioscience Industry and the Technology Platforms



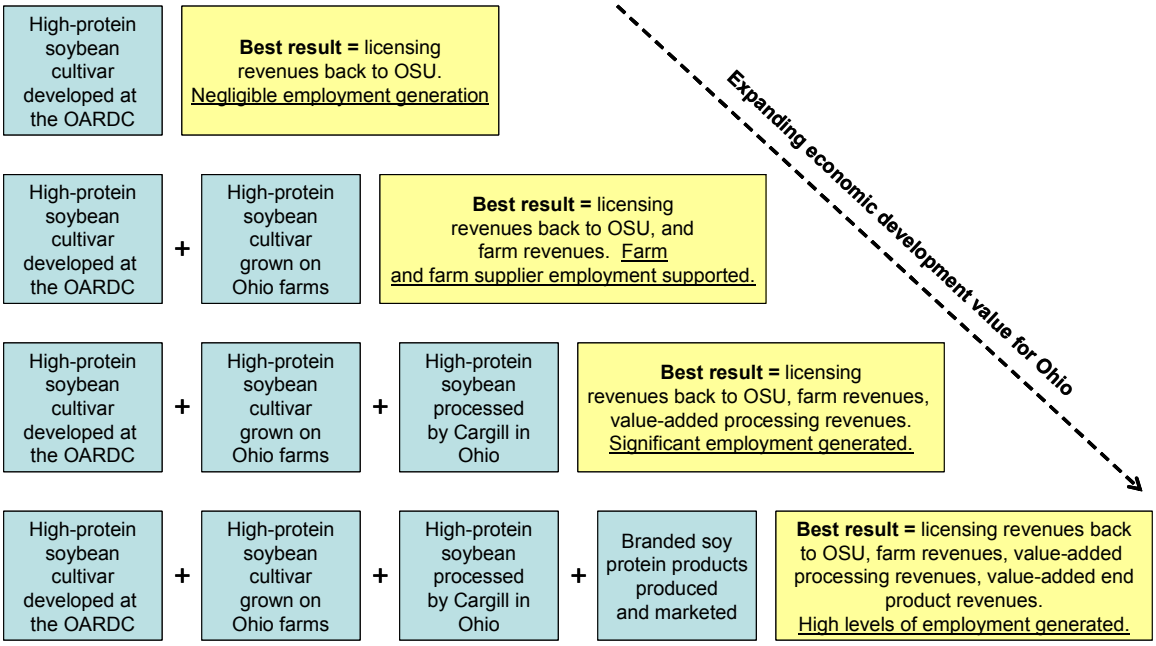
Direct links exist between the quantitatively established current and emerging industry strengths in Ohio's agbioscience sector and the core strength R&D platforms observed and recommended for OARDC and OSU. These mutually beneficial links are illustrated in Figure ES-5.

It is evident that definite opportunity exists to leverage the agbioscience technology platforms at OARDC to build upon the existing agbioscience industry base in the State of Ohio.

REALIZING ADDITIONAL VALUE FROM OHIO AGBIOSCIENCE

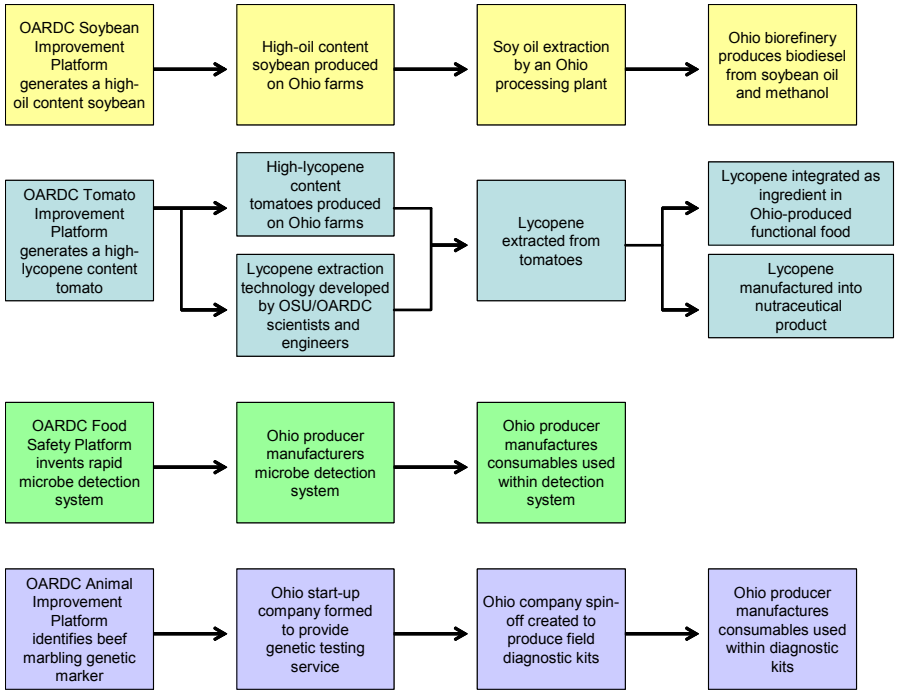
The future of agricultural and rural sustainability in a modern state such as Ohio will very much depend on the ability to construct "value-added" chains of production that vertically integrate agribusiness and agbioscience. Simply performing agbioscience R&D has a far lower potential economic return for Ohio than leveraging the discoveries from that science into an integrated production, processing, and manufacturing agbioscience sector. As Figure ES-6 illustrates, expanding levels of vertical integration, maintained within the borders of Ohio, yield expanding levels of economic development potential (in terms of business output and employment levels).

Figure ES-6. Multiple Stages of Value Capture from OARDC-Developed High Protein Soybeans



The technology platforms identified as priorities in this report lend themselves to economic development based on the formation of such value chains. The technology platform for enteric and food animal respiratory diseases, for example, could feed R&D discoveries into pilot- and production-scale sectors producing vaccines, diagnostic tests, drugs, and biologics. Likewise, the food safety platform could provide R&D discoveries related to pulsed electric fields that yield growth in Ohio's existing sterilization and decontamination equipment manufacturing sector. Further illustrative examples are provided on Figure ES-7.

Figure ES-7. Potential Integrated Value Chains for Ohio Based on OARDC Technology Platforms



A Broader Vision for Ohio Agbioscience and OARDC

Ohio's opportunities for building value-added clusters around core OARDC technology platforms could be facilitated by close, collaboratory relationships between industry sector representatives and the University. It is important to note that, in the "Biocentury," as the 21st century has been called, agbiosciences present a far broader opportunity for Ohio than only the identified OARDC/OSU core competencies. An opportunity exists to enhance and maximize the position of Ohio agbiosciences as a key driver of Ohio's Biocentury position. To facilitate this, a potential structure for OARDC is recommended that would position the Center for maximum impact in agbioscience economic development—building on key strengths and taking advantage of potential market directions.

The overall review of agbioscience trends at a macro level indicates that three primary development pathways are suited to the Center's expertise and future potential, and that these three pathways are a good match to the main categories in which future agbioscience development may occur. These three pathways could drive the growth of the following three distinct macro-economic sectors in Ohio:

- **Advanced Food Economy Development—**Leveraging OARDC expertise in food science and technology, in combination with advanced R&D skills in plant and animal breeding, nutrition, processing technologies, and food safety.
- **Biobased Economy Development**—Creating progress in biotechnology and biorenewable industrial commodities to generate an enhanced agbioscience economy and new fast-growth business fields for Ohio.
- **Environmental Economy Development**—Using OARDC strengths in environmental sciences, resource management, and environmental remediation to generate new environmental business technologies and promote an enhanced environmental sustainability and quality of life for Ohio.

These three macro opportunity areas would, perhaps, be best pursued under a formal structure designed to facilitate interdisciplinary work, collaboration with industry, innovation, and commercialization of agbioscience discoveries.

The overall structure of the proposed OARDC Ohio Agbioscience Initiative, with its three constituent Collaboratories and nine Programs, is shown in Figure ES-8. The figure also identifies key components of OARDC R&D that would contribute to the success of each Collaboratory.

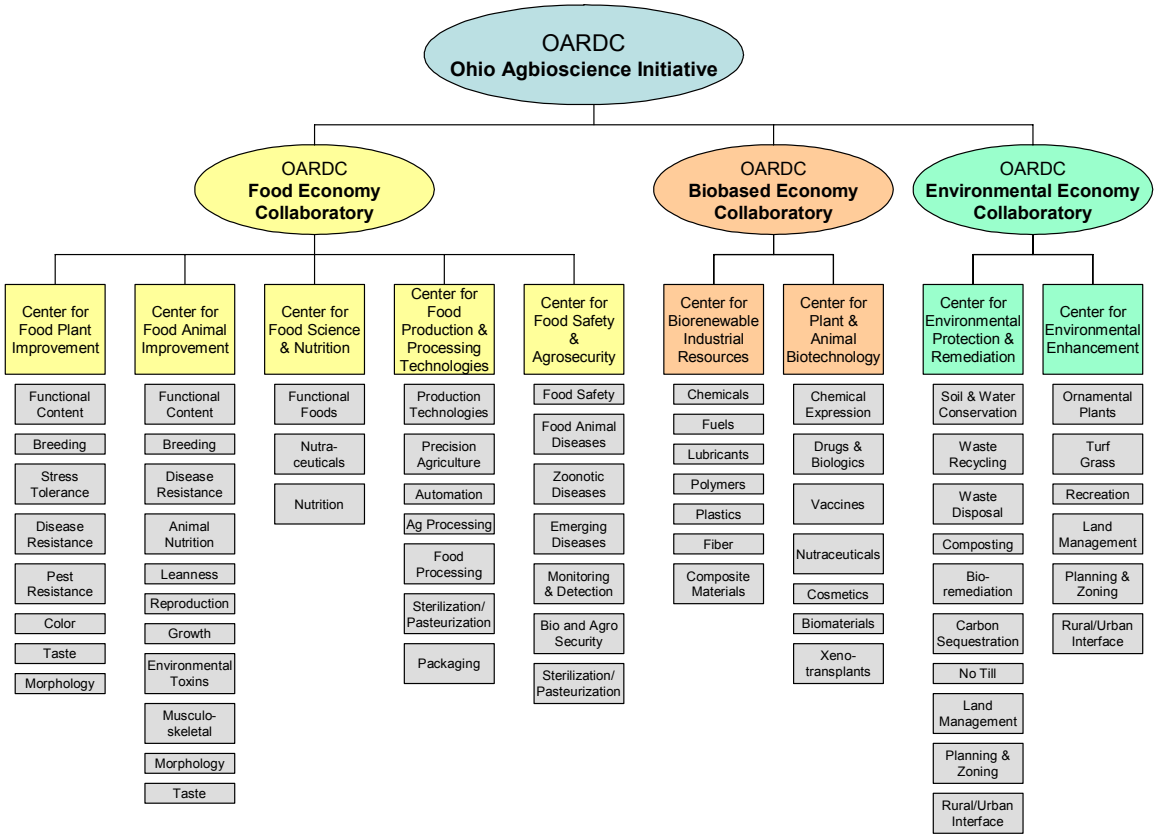
It is envisioned that the Collaboratories would foster both ***internal*** interdisciplinary research among faculty as well as ***external*** linkages and interaction with industry. First, from an internal perspective, it is envisioned that the organization and development of each Collaboratory should run concurrently, with faculty and research scientists from multiple OSU/OARDC departments being asked to sign on as members of one or more Collaboratories.

From an external economic development perspective, while still recognizing the importance of building OARDC's interdisciplinary research base, it is critically important to find ways in which to foster linkages with industry and commercialize that research. Technology commercialization involves bridging the gap between innovations and discoveries and the commercial development of those discoveries by agbioscience businesses. Overall, the external mission of the Collaboratories will be to transfer OARDC-developed technology and to assist companies seeking to commercialize new products and processes. The Collaboratories will serve to foster linkages with industry by

- Determining its research agendas based on industrial need, with industry driving the process

- Evaluating research coming out of the technology platforms to determine market opportunities through both technology and market assessments
- Evaluating commercial potential of patented technologies
- Forging partnerships with businesses interested in commercializing the agbiosciences
- Encouraging researchers to commercialize their research through licensing and spin-off opportunities and ongoing collaborations.

Figure ES-8. OARDC Agbioscience Initiative



CONCLUSION

The analysis undertaken and conclusions drawn in this study, *OARDC's Competitive Positioning Strategy: A Development Path for the Future,* represents the second phase of a three-phase effort. The third phase involved an independent external review and assessment of Battelle's findings regarding OARDC's contribution to Ohio's economy and its capacity to be an economic driver in the future. This external independent review team was comprised of four world-renown experts:

- Dr. Daryl B. Lund, Executive Director, North Central Regional Association of State Agricultural Experiment Station Directors and Professor of Food Engineering, University of Wisconsin-Madison;
- Dr. Clifton A. Baile, Distinguished Professor of Animal Science and Foods and Nutrition, and Georgia Research Alliance Eminent Scholar in Agricultural Biotechnology, University of Georgia-Athens;
- Dr. Neal Van Alfen, Dean of the College of Agriculture and Environmental Sciences, Professor of Plant Pathology, University of California, Davis; and,
- Dr. William R. Woodson, Director Indiana Agricultural Experiment Station, Professor of Molecular Biology, Purdue University.

The Assessment Team concluded that "In our opinion, it is not a stretch of the imagination that farming would not be nearly so attractive or profitable in Ohio if there were no agricultural experiment station…If it is assumed that the state's investment in OARDC (approximately $35M annually) went entirely to support agricultural production, then the state is investing 0.07% of the value of the agriculture sector…The challenge for OARDC leadership is to determine the appropriate balance between the broad research needs of the agricultural and environmental communities of Ohio and new investments in the core disciplinary competencies in research that have been identified in this study…The team believes that OARDC is well positioned to build upon its key strengths and leverage them for agricultural economic development. The Team supports the conclusion that the key focus must be to ensure that the proper infrastructure and investments are put in place to maximize the economic development potential for the agricultural industry."

This independent review affirms Battelle's findings that the biosciences have been identified as the underlying technology platform for the growth of state and regional economies in the coming decades. States are realizing that their traditional economic bases may undergo significant change and are increasingly embracing the biosciences, in all its forms, as a path to future economic progress. Agbioscience, with its connection to the immense plant and animal gene pool, is increasingly being seen as a key contributing component to current and future bioscience economic development.

This assessment of Ohio's strengths in the agbiosciences, gained through the research and operations of the OARDC, highlights significant agbioscience areas in which The Ohio State University and OARDC show strong core competencies upon which to build. More than 99 percent of the academic agbioscience R&D in Ohio is performed by OSU. Therefore, the agbiosciences present a unique opportunity to generate focused results through the efficient means of funding one institution.

Ohio has quite substantial strengths in all three legs of the "bioscience stool"—namely, human biosciences (at multiple academic medical centers) and animal and plant biosciences (at OSU). To a large extent, we anticipate that multidisciplinary approaches to agbioscience and bioscience issues in general will favor those states that can be a player in each of the bioscience fields. Ohio has this opportunity.

Significant agbioscience core competency platforms exist at OARDC and OSU. These strength areas are diverse and include plant sciences, animal sciences, agricultural and food processing technologies, and environmental sciences. Through further investment in sustaining and building upon OARDC's core agbioscience competencies, it is anticipated that significant agbioscience cluster growth can occur in Ohio.

The opportunities are such, however, that an even broader agbioscience investment approach could be adopted in Ohio. As envisioned, this would involve building a formal OARDC Agbioscience Initiative,

with three OARDC/Industry Collaboratories and associated R&D programs, focused on building Ohio's 21st century agbioscience position. The three collaboratories would focus specifically on bringing OARDC's agbioscience research expertise together with commercial agbioscience industry to work on pragmatic, applied projects to develop Ohio's

- Advanced Food Economy
- Biobased Economy
- Environmental Economy.

Building upon OARDC's strengths and gaining momentum for economic development in agbioscience for Ohio should be considered high priorities for the State of Ohio, given the likely preeminent importance of bioscience in general to a knowledge-driven, 21st century economy.

Introduction

The 21st century has opened to a salvo of predictions regarding the emergence of the "innovation economy," "knowledge economy," "biotech century," and other technology-based economic transformations. Despite the current hyperbole, it should be recognized that economic growth has always been sustained by innovation and the advancement of knowledge. For instance, the mechanical loom transformed the fabric industry, and the assembly line modernized the production of goods and led to what is now known as the Industrial Revolution. Likewise, the computer has galvanized business processes across all industry sectors, just as the recent findings from the Human Genome Project will revolutionize the biosciences in the future. In addition, as sails and horses were replaced by engines in ships and rail in the 19th century and widespread development occurred in the automotive and aircraft industry in the 20th century, these innovations led to the opening and enhanced dramatically the globalization of the world's markets. In many respects, agriculture has been on the forefront in incorporating technological advances through the mechanization and now computerization of the industry and the introduction of new crops. It also is a leading innovator through advancements in areas as diverse as nutraceuticals, bioenergy, and biotechnology.

The knowledge economy is not, therefore, "new." As one pundit noted, "I have never seen a successful economy built on ignorance." So, what has led to the current excitement regarding innovation and the preeminent importance of technology and knowledge advancement to a successful U.S. economy? Two fundamental forces are at work:

- The pace of scientific discoveries and the technologies to which these discoveries give rise is accelerating rapidly (i.e., advances in genetics have dramatically accelerated the discovery process in the life sciences). Furthermore, the opportunity to speed the discovery process, in concert with the ability to protect and profit from intellectual property (IP), is leading to an innovation race among competing nations, states, and regions.
- World markets are global, and pressure is accelerating on the United States to maintain its high-wage/high-skill employment base by consistently staying ahead of other nations in terms of technology and productivity measures.

Consequently, an innovation economy *per se* is not a new phenomenon; rather, technological and scientific innovation has increased in importance as a, ***if not the***, fundamental impetus of economic growth and competitiveness among developed nations.

The State of Ohio has a long history of contributions to the nation's innovation economy. Indeed, even the state's license plate is a testimony to invention, highlighting Ohio's role as the "Birthplace of Aviation." Leading inventions made by Ohioans have included electric lighting (Thomas Edison, Charles Brush, and Arthur Compton), aluminum processing (Charles Hall), general anesthetics (Ernest Volwiler), the spectrometer (Willard Bennett), and the water turbine for hydroelectricity (Lester Allan Pelton). Ohio is home to numerous research universities, federal laboratories, and private research institutions, all of which serve as innovation and knowledge hubs for the state.

Specifically, research and development (R&D) in the agricultural bioscience (agbioscience) field has been a consistent contributor to Ohio's innovation economy. Since its creation by the Ohio General Assembly in 1882, the Ohio Agricultural Research and Development Center (OARDC)—known as the Ohio

Agricultural Experiment Station until 1965—has contributed a regular flow of applied R&D discoveries in the following diverse areas:

- Food processing and preservation technologies
- Processes for adding value to commodity crops
- New and improved crop cultivars with enhanced quality, yield, and disease/pest resistance characteristics
- Diagnostics, vaccines, and treatments for animal infectious diseases
- The application of genomics, post-genomic sciences, and biotechnology to the development of new tests, diagnostics, plant varieties, and novel products from biomass.

Much attention has been paid in state economic development circles to the importance of the "bio-sciences" as a 21st century technology growth area. Multiple states have worked to develop bioscience development plans; but, to a large degree, much of the focus has been on applying the biosciences to human health (developing drugs, diagnostics, devices, replacement tissue, and instruments). While applications to human health hold significant economic potential, so too does the application of the biosciences to food animal health; agricultural productivity; value-added agricultural and food products; and new materials, chemicals, biologics, and fuels developed via biomass pathways.

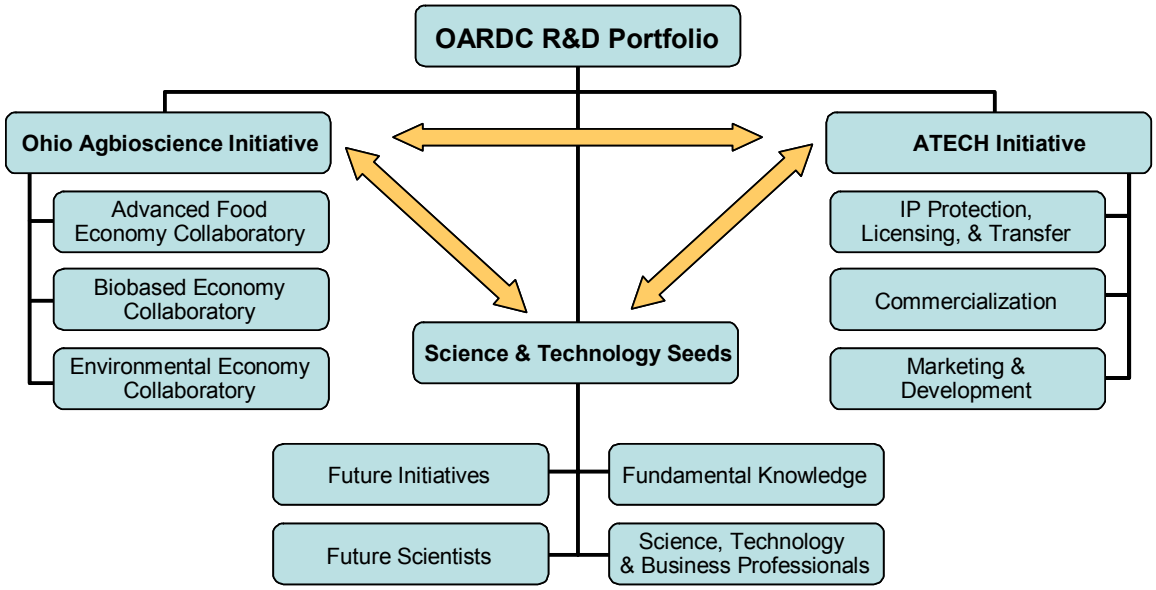
Specifically, the biosciences, as they relate to the plant and animal biosphere, contain a truly huge repository of genes, the novel combination and mining of which have the potential to spur dramatic changes in many industries ranging from medicinal and food products to advanced materials and energy sources. But, beyond genetics, traditional agbioscience and agricultural engineering have a great deal to contribute in terms of new production and processing technologies, new and improved products from agricultural commodities, and the novel application of biomass resources to yet undiscovered economic uses. Against this background, it becomes clear that the presence and ongoing operations of an applied agricultural research and development center provide a likely comparative advantage for states engaged in growing their innovation and bioscience economy.

The recent report, *OARDC: A Generator of Positive Economic Impacts for Ohio* (Phase I of this two-phase effort), profiles the past, current, and likely future economic benefits accruing to the State of Ohio from the ongoing operations of OARDC. The report highlights the legacy of agbioscience benefits and innovation in Ohio that has originated from OARDC functions and also areas of opportunity for increasing agbioscience benefits to the state. While the impact report centers attention on some of OARDC's potential for significantly advancing Ohio's position in the biosciences, further analysis was required to understand OARDC's bioscience core competencies and specific technology platforms upon which to build substantial economic progress for Ohio. To this end, OARDC hired Battelle's Technology Partnership Practice (TPP) to perform an independent evaluation of The Ohio State University's (OSU's) current position in agbioscience—conducting a study that would

- Identify the existing and emerging comparative advantages of OARDC and OSU in the field of agbioscience
- Highlight the key high-growth market sectors of the Ohio economy where OARDC could have the most positive impact
- Profile the critical investment points that are likely to yield above average wages and job growth in Ohio from OARDC research.

This study reports the findings of research and strategic planning activities, targeting the three issues listed above. Specifically, the study identifies seven technology platforms in which OARDC has a demonstrable track record of R&D success and which show promise for future development. In addition, these seven platforms at a macro level indicate that three primary development pathways are suited to OARDC's expertise and the market needs of Ohio's agbioscience industry. It is within that conceptual framework that three Collaboratories are proposed, as diagrammed on the left-hand side of Figure 1.

Figure 1: OARDC R&D Portfolio



However, as this analysis unfolds, it is important to keep in mind that the Ohio Agbioscience Initiative is but one element of the triumvirate. It is critical that the OARDC balances its activities in the following three areas:

- Targeting initiatives to support the existing and emerging industrial base
- Promoting new innovative industrial technologies that promise continual economic growth, through its science and technology seed initiatives
- Commercializing, licensing, and marketing its technology through its ATECH Initiative.

The Agbioscience Industry in Ohio: Trends and Developments

INTRODUCTION

The agbioscience industry is a set of knowledge-based sectors that, together, form a cluster of established and emerging opportunities. This cluster is constantly altered and reinvented as scientists, engineers, and researchers gain new insights in plant and animal genetics, nutrition, and health. Advances in the agricultural sector have shifted agriculture's focus beyond producing food and fiber toward improving public health, social well-being, and the environment. Agriculture is playing a new and different role in delivering nutritional, pharmaceutical, and bio-based products; in providing sound stewardship of resources; and in supporting rural communities. These technological breakthroughs take shape in new and innovative products used in everyday life. This explains, in part, the reason why public officials, private investors, and academic scholars have watched developments in agbioscience with intense interest.

The industry's ability to continually reinvent itself indicates the potential that the agbiosciences have to spur new economic activity. The implications of new, life-altering discoveries are elevating agbioscience to the level of a high value-adding industry sector. Countless new commercial prospects emerge with every new breakthrough and discovery.

The encompassing nature of the industry has positioned agbioscience as a growing sector of the economy. The industry has given rise to new establishments and increasing employment. Over the past five years, the agbioscience industry has grown by 8 percent across the United States, adding more than 190,000 jobs nationally.[3]

The inherent diversity of the agbioscience sector is a strong factor contributing to the growing industry focus. The cross-cutting technologies embedded in the agbiosciences have led many companies to pursue market opportunities in associated technologies, from bio-engineered foods and fuels to advanced new botanical medicines, from breeding healthier animals to genome mapping—each contributing to the advancement of life science activities, whether related to plant, animal, or human health discoveries and opportunities.

The United States is a world leader in many areas of agbioscience endeavors—agbioscience research, design and production of new technologies, healthier agricultural and food commodities, and new drugs and nutraceuticals. Since interactions between researchers and practitioners are vital for continued advancement and progress within the sector, the agbiosciences have tended to concentrate in certain regional economies in the nation where such relationships are prevalent. The State of Ohio potentially can develop its agbioscience expertise and become a value-adding asset for the industry. The opportunity exists to support current emerging subsectors in the agbioscience industry and reinforce existing specializations.

This economic analysis section examines the agbioscience industry within the State of Ohio as it existed in 2003. The section describes the general performance of the agbioscience sector over the past several

[3] The agbioscience industry includes the following subsectors: agricultural services, food processing, agricultural processing, drugs and pharmaceuticals, organic and agricultural chemicals, agricultural machinery and equipment, biological research and testing, and agricultural research and testing.

years and compares this experience with national trends. This analysis further identifies emerging and existing subsector industry strengths which, along with OARDC's research core competencies analysis to be described later, provide the basis to better link research excellence to economic opportunity in Ohio.

WHY FOCUS ON THE AGBIOSCIENCES?

The bioscience industry is a strong driver for the national and Ohio economies, diversifying the economic base, offering good, well-paying jobs, and contributing to overall economic productivity. However, with national and global competition intensifying, the state's performance within particular sectors of the agbiosciences is not necessarily the pattern for the future. Therefore, it is appropriate that the private and public sectors jointly consider and address ways to ensure Ohio's competitive base and future in this agbioscience industry cluster.

There are a number of reasons to target Ohio's agbioscience industry for economic development:

The agricultural and food sector industry is a significant part of the Ohio state economy. Examining all industry sectors impacted by the agbiosciences, which include the entire agricultural and food sector industry, revealed that the industry is big business in Ohio. For instance, study of the first component of the extremely vertically integrated market revealed that in 2002 Ohio contained 78,000 farms, covering a total of 14.7 million acres—fully 56 percent of Ohio's total land area of 26.4 million acres—impacting a widespread geographic area in the state. Furthermore, a recent examination of the entire agriculture and food sector industry in Ohio revealed that it employs more than 1 million Ohioans and has a total economic output of $79.6 billion, 12 percent of the Ohio economy.[4]

The agbioscience industry has a wide-ranging impact on industries not typically perceived to be linked with agbioscience technology. Examining the agbioscience industry from a macroeconomic perspective revealed that the industry is a broad-based sector of the economy. Industries are increasingly integrating new technologies in a variety of ways to raise productivity and product capabilities. The innovative nature of the agbioscience industry has positioned it as a value-adding sector of the economy.

The diverse industrial applications of the agbiosciences are attributable to the innovative capacity of the industry in both the agriculturally related and clinically related fields. New market opportunities have merged as a result of scientific and technological innovations and discoveries. New food technologies are leading to methods to control food-borne pathogens and enrich the nutritional value of crops, such as vitamin-A-enriched rice. Genetically modified crops resistant to insects and diseases produce higher yields, lower production costs, and reduce the use of pesticides and chemical fertilizers. Materials produced from maize are being used to create polylactide plastics, which are then used in clothing and packaging. New precision farming equipment is incorporating advanced electronic systems to monitor soil conditions to improve crop yields and reduce harmful environmental impacts. All these advances demonstrate that the agbioscience industry has the potential to spur new economic activity across several industry sectors.

[4] Sporleder, Thomas L. 2003. "OHFOOD: An Ohio Food Industries Input-Output Model – Version 6.0." The Ohio State University Department of Agricultural, Environmental, and Development Economics. June.

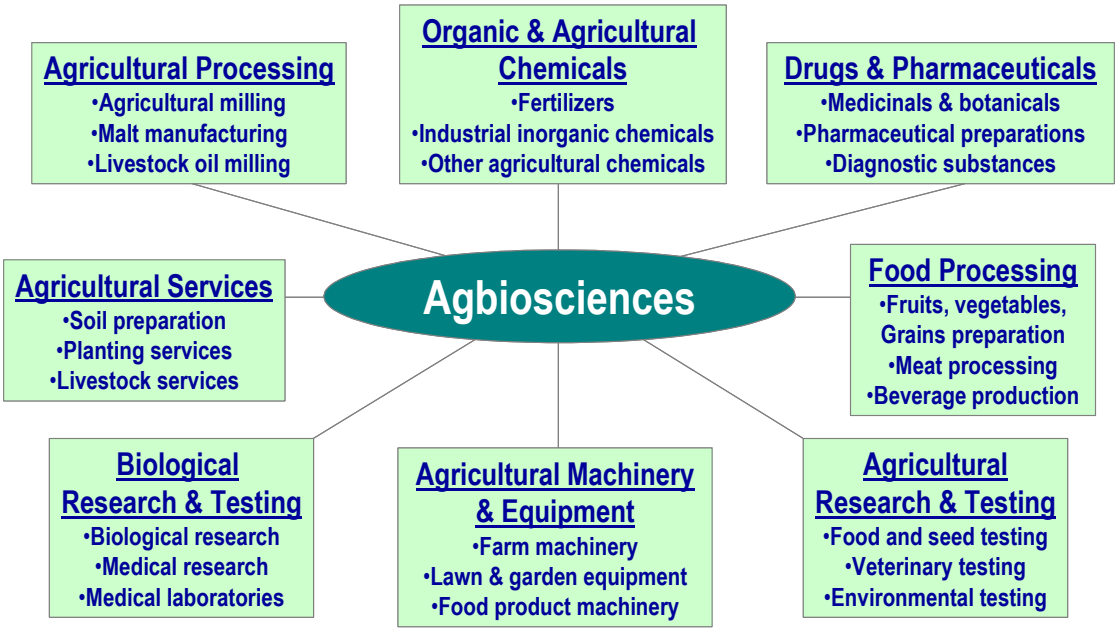
DEFINITION OF OHIO'S AGBIOSCIENCE CLUSTER

Varying industrial classifications could be used to define the agbioscience sector of the economy. Currently, there is no commonly accepted definition of the industry. Categorization is difficult because of the diversity of agbioscience activity. The industry is dynamic and encompasses a wide variety of industrial applications, and continual innovation further complicates defining the industry. Agbioscience advancements are constantly being applied in new and different ways, creating new industry sectors, such as genetically improved foods, or alternate energy sources, such as agriculturally based fuels.

Eight Major Subsectors

Figure 2 shows the eight major subsectors of agbioscience activity identified for this economic analysis.[5] Table A-1 in Appendix A lists the four- to eight-digit Standard Industrial Classification (SIC) industries selected for each of the eight major subsectors.

Figure 2: Breakout of the Agbioscience Industry



It is important to note that, for the purpose of the following analysis, only these eight subsectors were examined. The technological advances that these subsectors are adopting, in particular the research and testing subsectors, have significant impact on many more traditional agricultural industries, such as commodity and livestock production and landscape and horticultural services, in addition to a significant portion of the environmental industry.

[5] Enclaves of economic activity may remain that are related to the biosciences but not included in this list. In part, this reflects the inadequacy of the current industrial classification code to categorize agbioscience activity. It also is symptomatic of the convergence precipitated by the diversity and expanse of the agbioscience sector.

Data and Methodology

Clearly, this set of agbioscience subsectors subsumes much of the supplier chain—a key characteristic of cluster analysis—including such subsectors as agricultural machinery, agricultural processing, and agricultural chemicals. The intention is to define the cluster, not narrow the industry sectors. Unfortunately, the industrial classification system will not incorporate fully the wide variety of industrial activity that falls within the scope of the agbioscience industry. It is possible that enclaves of economic activity remain that are related to the agbioscience industry but are not included in this list. Characterizing an industrial sector solely on the basis of aggregated industrial data will inevitably result in certain data gaps.

This economic analysis primarily examined employment and establishment information obtained from the MarketPlace survey administered by the Dun & Bradstreet Corporation. The survey is performed on a quarterly basis. The data in this analysis were taken from the fourth quarter of 1998 and first quarter of 2003.[6] Additional establishment detailed data were collected using corporate and industry Web sites.[7]

THE AGBIOSCIENCE SECTOR IN AGGREGATE

When the agbioscience industry is examined in its entirety (i.e., the total combination of the eight subsectors), it can be seen as a growing sector of the national economy. Between 1998 and 2003, establishments grew by 23 percent and employment by 8 percent across the nation. In 2003, almost 84,000 establishments were actively engaged in the agbioscience sector. This accounts for employment of more than 2.8 million people (Table 1).

[6] The first quarter 2003 data were the most recent data available at the time this economic analysis was begun. Since only portions of the *MarketPlace* data are updated in any particular quarter, the data should not vary much by quarter in any systemic fashion. This analysis refers to years only.

[7] Note that the reporting units of economic activity are establishments, which are not the equivalent of firms, as companies may own and operate multiple establishments.

Table 1: State and National Agbioscience Comparison

Metric	State of Ohio	United States
Establishments, 1998	**2,241**	68,115
Establishments, 2003	**2,839**	83,740
Change in establishments	**598**	15,625
% Establishment Growth	**26.7%**	22.9%
Employment, 1998	**90,062**	2,560,422
Employment, 2003	**92,303**	2,753,732
Change in employment	**2,241**	193,310
% Employment Growth	**2.5%**	7.5%
Employees per establishment, 1998	**40.2**	37.6
Employees per establishment, 2003	**32.5**	32.9
% Share of private sector employment, 1998	**1.76%**	2.17%
% Share of private sector employment, 2003	**1.65%**	2.06%
Employment location quotient, 1998	**0.81**	na
Employment location quotient, 2003	**0.80**	na
Change in employment location quotient	**-0.01**	na
All private sector activity:		
Total Employment, 2003	**5,579,902**	133,665,444
% Establishment growth, '98-'03	**23.4%**	21.3%
% Employment growth, '98-'03	**9.2%**	13.5%
Employees per establishment, 2003	**12**	10

Source: Battelle calculations from Dun & Bradstreet MarketPlace *Surveys*
Note: % Share of private sector employment *is the % share of the reference region's total employment.*

In comparison, the number of agbioscience firms in Ohio is growing at an even faster pace than in the nation. In 2003, agbioscience establishments numbered 2,839 throughout Ohio, thereby increasing since 1998 at a faster rate than the national average. The establishment growth rate in Ohio between 1998 and 2003 was 27 percent, compared with the national establishment growth rate of 23 percent.

However, employment in the agbioscience sector was below the national growth rate. While agbioscience employment in the State of Ohio rose in the five years since 1998, the increase was below that of the United States. Nationally, agbioscience employment grew at a rate of 7.5 percent, compared with 2.5 percent at the state level. The total employment level in the agbioscience sector in Ohio in 2003 was 92,303 employees.

Key Facts:
State of Ohio Agbioscience Industry, 2003

- **2,839 establishments**
- **92,303 employees**
- **27% establishment growth, '98-'03, outpacing national growth of 23%**
- **2.5% employment growth, '98-'03, compared with 7.5% national growth**
- **Location quotient 0.80**

Overall, Ohio is less specialized in the agbiosciences than the nation. The location quotient is another way to measure an industry's level of concentration within an economic region.[8] Ohio's agbioscience location quotient is 0.80, indicating that agbioscience employment is approximately 20 percent less concentrated in the state than nationwide.

OHIO'S AGBIOSCIENCE CLUSTER SUBSECTORS

The innovative nature of the agbioscience industry has positioned it as a value-adding sector of the economy. The innovative capacity is due, in part, to the wide range of industrial applications of the agbiosciences. Therefore, the diverse activity within the sector requires an analytical approach that examines individually the eight subsectors that compose the agbioscience industry to fully understand the complexity of the market. This subsector analysis also helps to define the unique characteristics of the industry in the context of the state economy and to identify existing strengths and emerging potential subsectors.[9]

In Figure 3, Ohio's agbioscience subsectors are categorized into four classes based upon their performance between 1998 and 2003. A subsector is assigned to a category based on its growth relative to U.S. growth and its location quotient. The four classifications of subsectors are stars, emerging potential, transitional, and divergent. Subsectors classified as stars or emerging are vital for the overall industry and its future development potential. These subsectors are often seen as the driving force behind the industry's future success. Subsectors classified as transitional or divergent are in a declining or evolving stage. Though not irreversible, these subsectors demonstrate performance below the national average and could threaten the long-term viability of the industry in Ohio.[10]

[8] Location quotients are a common measure of the concentration of a particular industry or industry sector in a region relative to a reference area. The location quotient consists of the ratio of the share of total regional employment that is in the particular industry and the share of total employment in the reference area that is in the particular industry:

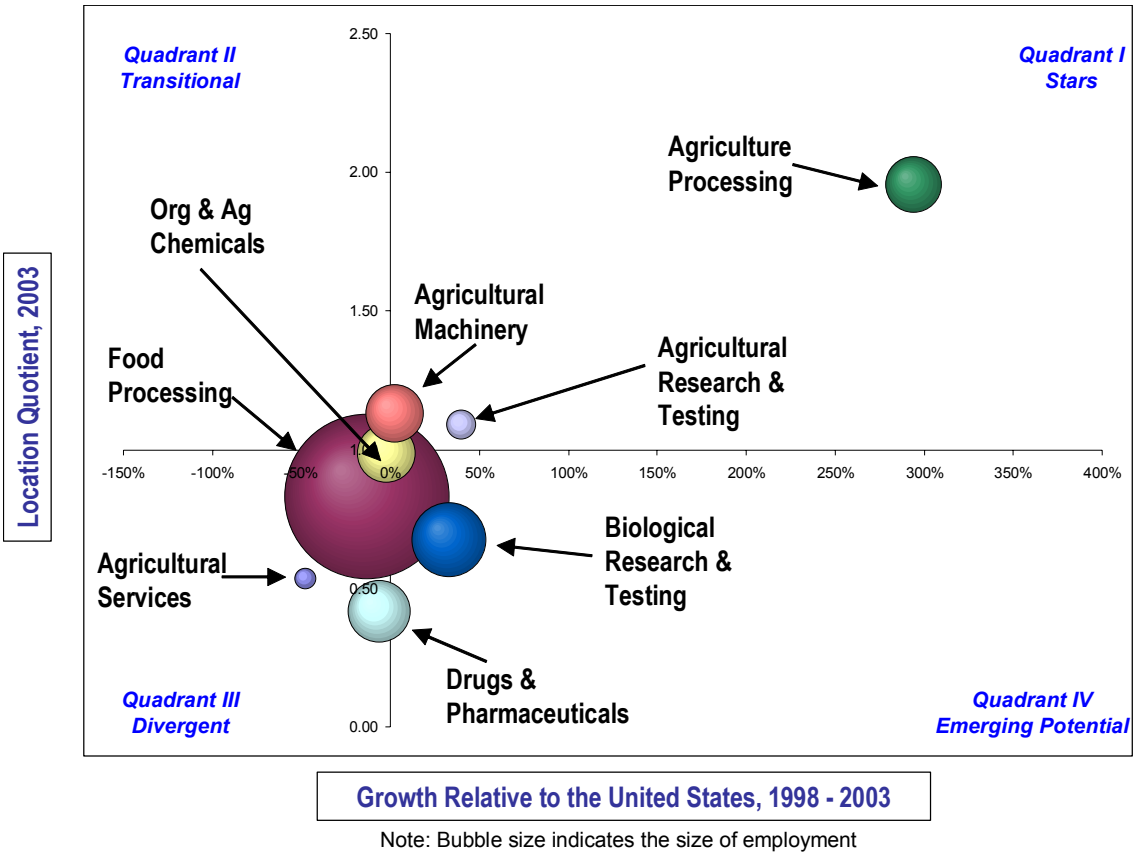
$$\textit{Location Quotient} = \frac{\left(\frac{\text{regional industry employment}}{\text{regional total employment}}\right)}{\left(\frac{\text{reference area industry employment}}{\text{reference area total employment}}\right)}$$

A location quotient greater than 1.0 indicates that the region is relatively concentrated in the particular industry, whereas a location quotient less than 1.0 signifies relative under-representation. Throughout this report, location quotients are used to report state and regional industry concentrations relative to the United States.

[9] Examining specific subsectors of the industry should be done with caution. At the detailed subsector level, smaller absolute numbers may exaggerate standard metrics and comparisons. In such instances, the loss or gain of one establishment may skew the data.

[10] A detailed table of Ohio's bioscience subsector performance can be found in Appendix B.

Figure 3: Ohio Agbioscience Cluster Subsector Performance, 1998–2003



Note: Bubble size indicates the size of employment

NOTE: The large increase in Agricultural Processing jobs in Ohio between 1998 and 2003 is attributed to the relocation of a major operating unit of Procter and Gamble. According to the Onesource Corptech database, the operating unit of Norwich-Eaton Pharmaceuticals Inc., a subsidiary of P&G since 1982, was relocated to Cincinnati, Ohio, in November 1998. Dun & Bradstreet did not record this change until the subsequent year. Therefore, as a result of the relocation, approximately 5,000 jobs were added to the Agricultural Processing subsector, producing an overall growth rate of 287 percent within the subsector.

Stars

Agricultural processing is the fastest-growing subsector in Ohio relative to the nation and is regionally specialized. Between 1998 and 2003, the subsector almost quadrupled in size, adding more than 4,600 jobs. The subsector had an employment base of 6,220 in 2003 across 37 establishments. This employment increase of 287 percent is substantial considering that, at the national level, the subsector experienced a 7.2 percent decline in employment.

Its growth in Ohio has positioned this subsector well above the national employment concentration level. The state's employment concentration in agricultural processing is almost twice the national average. This level of employment makes agricultural processing in Ohio significantly specialized. In addition to the regional specialization, Ohio's employment level represents an increasing concentration. The subsector's fast-paced growth is a major reason for the state's growing specialization.

However, it is important to note that this significant growth and specialization can be seen as the result of the prior acquisition and eventual relocation of one establishment to Ohio during this time frame. The large increase in agricultural processing jobs in Ohio between 1998 and 2003 is attributed to the relocation of a major operating unit of Procter and Gamble. According to the Onesource Corptech database, the operating unit of Norwich-Eaton Pharmaceuticals Inc., a subsidiary of P&G since 1982, was relocated to Cincinnati, Ohio, in November 1998. Dun & Bradstreet did not record this change until the subsequent year. Therefore, as a result of the relocation, approximately 5,000 jobs were added to the agricultural processing subsector, producing an overall growth rate of 287 percent within the subsector.

Agricultural research and testing is another fast-growing subsector in Ohio relative to the United States; although it is not considered to be regionally specialized, it is more concentrated in Ohio than in the nation. Between 1998 and 2003, the subsector added more than 456 jobs. It had an employment base of 1,720 in 2003 across 73 establishments. This employment increase of 36 percent is significant considering that, at the national level, the subsector experienced a 3.8 percent employment drop.

The strong growth in Ohio has led the subsector from a position of relative weakness (25 percent less concentrated than the nation) to a current employment level that is 9 percent more concentrated than the national employment level. In addition, the subsector's strong growth rate would indicate that this trend in its concentration level will continue. This is critically important to growing the technological strength of the state's agbioscience industry, because the majority of R&D occurs within this subsector. Ohio's agricultural research and testing "star" categorization bodes well for future growth and economic impact.

Agricultural machinery, while hovering at the median, does show a positive growth rate and a greater concentration level relative to the nation. Between 1998 and 2003, the subsector had steady growth of 4.1 percent in Ohio. This rate of growth is more than twice the national growth rate of 2.0 percent. Ohio is currently 13 percent more concentrated than the nation within this subsector; however, this concentration level may be threatened if the employment growth rate does not maintain pace with the nation. Interestingly, however, the number of establishments within the subsector grew by more than 80 percent, indicating that the relative employment size within firms dropped significantly. This disparity might indicate downsizing or death rates among existing firms and at the same time, creation of a significant number of new firms.

Emerging Potential

Biological research and testing is the second fastest-growing agbioscience subsector and outpaced growth of this industry at the national level.[11] Over the 5-year time period between 1998 and 2003, subsector employment in biological research and testing increased by 75 percent. The increase brought employment levels above 10,000 across approximately 800 establishments. The growth that Ohio experienced in biological research and testing even surpassed the U.S. growth rate. Nationally, biological research and testing grew at a rate of 42.3 percent. The ability of the subsector to remain ahead of national employment growth rates has contributed to a rising employment concentration. However, the

[11] It is important to note that Cincinnati Children's Hospital Medical Center was classified originally as a Specialty Hospital (SIC 8069) in 1998. In 2003, the classification changed to Noncommercial Research Organization (SIC 8733). This often occurs with hospitals performing research activities in addition to providing primary healthcare services. However, including employment of research hospitals in codes reserved for organizations exclusively performing research activities over-estimates the actual level of research employment at hospitals. Typically, the majority of hospital employment is not performing research activities. Therefore, the 2003 employment for Cincinnati Children's Hospital Medical Center was removed from the biological research and testing subsector and reclassified as hospital employment.

employment concentration level in Ohio remains approximately 30 percent below the national average. That said, the positive growth rate and concentration level increase are positive signs for future economic impact because the biological research and testing subsector, much like the agricultural research and testing subsector, provides the building blocks for the future growth of other agbioscience subsectors.

Transitional

No agbioscience subsectors appear in the transitional quadrant for Ohio.

Divergent

The drugs and pharmaceuticals subsector is growing but at a rate below the national average. Between 1998 and 2003, subsector employment in drugs and pharmaceuticals increased by 16 percent. At the same time, the number of establishments increased by approximately 50 percent, with Ohio accounting for 149 firms in 2003. However, the employment growth that Ohio experienced in drugs and pharmaceuticals was less than the national growth rate of 22.3 percent. Furthermore, the concentration of the subsector in Ohio, which was approximately 60 percent less than in the nation, actually declined by 1 percent over the time period. Therefore, although the subsector is growing in Ohio, it is not keeping pace with national growth trends and, therefore, is losing relative concentration.

Food processing is the largest subsector in terms of employment, by far, but is in a state of decline. Between 1998 and 2003, the subsector lost 12 percent of its employment base. This decline is significant in light of the 1.5 percent positive growth demonstrated at the national level. The decline in Ohio employment represented a loss of approximately 7,250 jobs, leaving the food processing subsector employing 52,750 individuals across 1,142 establishments in 2003. Ohio's declining employment base resulted in a reduced employment concentration within the state. In 2003, food processing in Ohio was 17 percent less concentrated than in the nation, compared with only 7 percent less concentrated in 1998.

The organic and agricultural chemicals subsector is approximately as concentrated in Ohio as in the nation; however, it is experiencing employment decline. Between 1998 and 2003, the subsector loss 10.6 percent of its employment base. This level of employment loss was greater when compared with the 8.0 percent decline across the nation. However, the concentration level varied by only 1 percent over the time period, leaving the organic and agricultural chemicals subsector only 1 percent less concentrated than the nation. But, if this employment decline continues, the concentration level can be expected to decline over time.

Agricultural services experienced the largest decrease in terms of employment and is well below the national concentration average. Between 1998 and 2003, the subsector loss 42 percent of its employment base in Ohio. This fast-paced decline is in sharp contrast to the positive growth demonstrated at the national level. The U.S. agricultural services subsector grew at a rate of 6.3 percent. In addition, the subsector is the smallest in terms of employment base among the eight agbioscience subsectors, employing 828 individuals across 273 establishments in 2003. Interestingly, the number of establishments for the agricultural services subsector actually increased 16 percent for the period, for a net gain of 38 firms. This indicates that the employment size within these establishments in decreasing.

The rapidly dwindling employment base has drastically reduced the level of employment concentration within the state. Agricultural services is almost 50 percent less concentrated in Ohio than in the nation and is extremely small in size. This is a decrease of 40 percent in its level of concentration over the analysis period.

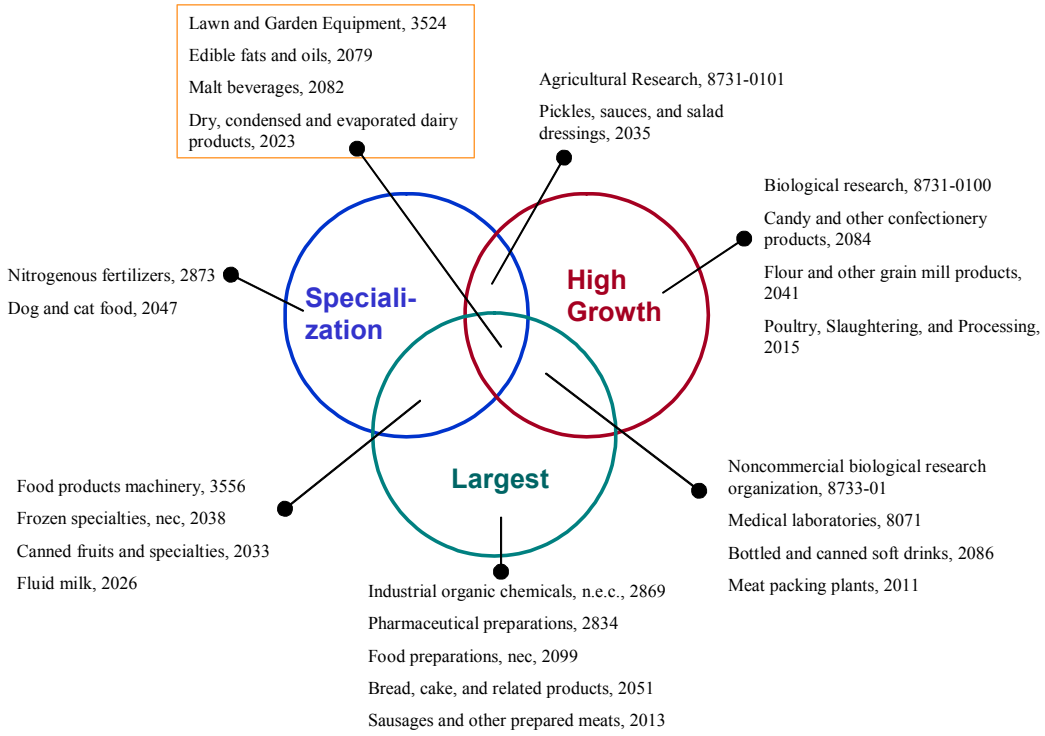
Cluster Subsector Strengths in Detail

It is useful to further isolate particular strengths of the subsectors. However, examining industry-specific information available at the six-digit SIC code level should be done with caution. At such a detailed level, the data are often suppressed to avoid revealing information specific to individual firms. The detailed analysis also can result in smaller absolute numbers and thereby exaggerate standard metrics and comparisons. In spite of these limitations, the disaggregated data potentially can reveal sources of subsector strength.

Figure 4 depicts the performance of key agbioscience subsectors in the State of Ohio. The industries were chosen based on three criteria:[12]

- Industries that possessed an employment concentration of 1.20 or greater were determined to be a regional specialization.
- Industries that grew above the national growth rate were determined to be high growth.
- Industries were classified as "large" based on employment size equal to or greater than 500.

Figure 4: Assessment of Ohio's Agbiosciences Cluster Detailed Industry Strengths



Detailed industries that fall within the confluence of the three criteria circles are represented as overlapping major strengths of agbioscience cluster subsectors. These industries exhibit very large employment bases, significant specializations, and growth over the past year that surpasses U.S. growth rates. Table 2 presents the data for those target industries possessing at least two of the criteria used to identify strong detailed industries.

[12] To avoid overstating trends, this analysis included only those industries with an employment level of at least 500.

Table 2: Industry Strengths of Ohio Agbioscience Detailed Clusters

Primary Target Industries - Large, Growing, and Regionally Specialized			
2079	Edible fats and oils	Employment:	5,750
		Growth:	819%
		Specialization:	9.92
2023	Dry, condensed and evaporated dairy products	Employment:	2,193
		Growth:	145%
		Specialization:	2.85
3524	Lawn and Garden Equipment	Employment:	2,192
		Growth:	47%
		Specialization:	2.34
2082	Malt beverages	Employment:	2,003
		Growth:	19%
		Specialization:	1.37
Large Anchors - Large Employment and Regionally Specialized or High Growth			
8071	Medical laboratories	Employment:	7,449
		Growth:	53%
		Specialization:	0.71
2086	Bottled and canned soft drinks	Employment:	5,297
		Growth:	33%
		Specialization:	0.96
2038	Frozen specialties, nec	Employment:	4,331
		Growth:	-34%
		Specialization:	2.2
2026	Fluid milk	Employment:	4,111
		Growth:	-34%
		Specialization:	1.94
2033	Canned fruits and specialties	Employment:	3,545
		Growth:	-5%
		Specialization:	1.33
3556	Food products machinery	Employment:	3,150
		Growth:	3%
		Specialization:	2.15
2011	Meat packing plants	Employment:	2,968
		Growth:	1%
		Specialization:	0.49
8733-01	Noncommercial biological research organization	Employment:	2,064
		Growth:	118%
		Specialization:	0.74
Emerging Industries - High Growth and Regionally Specialized			
2035	Pickles, sauces, and salad dressings	Employment:	978
		Growth:	89%
		Specialization:	1.19
8731-0101	Agricultural Research	Employment:	803
		Growth:	26%
		Specialization:	1.20

Table 2 shows those industries that are likely to represent critical strengths of the Ohio agbioscience cluster. These industries, each possessing a pair of critical characteristics, can be used by the state to help bolster the entire agbioscience base. Adhering to these metrics, these industries demonstrate the potential for the state to create new opportunities and niches in the agbioscience industry which can be leveraged to jump-start other promising industry sectors. The diversity of the agbioscience cluster industries clearly indicates that advancements within particular subsectors can spill over and become a platform to strengthen others. The state can build a promising future in the agbiosciences by focusing on its existing strengths.

CONCLUSIONS

The number of agbioscience firms in Ohio is growing at a pace faster than in the nation. However, employment in the agbioscience sector is below the national growth rate. This slower-than-national-employment growth rate has led to Ohio being only 80 percent as concentrated in the agbiosciences as the nation.

The economic analysis of the Ohio agbioscience economy indicates that the industry is being led by three subsectors (Table 3). These three subsectors in particular are well positioned to be the foundation of a comprehensive economic-developed strategy. Agricultural processing is the fastest-growing subsector in Ohio relative to the nation and is regionally specialized. Agricultural research and testing is another fast-growing subsector in Ohio relative to the United States; although it is not considered to be regionally specialized, it is more concentrated in Ohio than in the nation. Agricultural machinery, while hovering at the national average, does show a positive growth rate and a greater concentration level relative to the nation.

Table 3: Key Ohio Agbioscience Subsectors

Subsector	2003 Employment	Location Quotient	Employment Growth 1998–2003
Agricultural Processing	6,220	1.96	287%
Agricultural Research and Testing	1,720	1.09	36%
Agricultural Machinery and Equipment	6,579	1.13	4%

To create a more durable and vibrant agbioscience industry, OSU through OARDC must target initiatives to support existing strengths and encourage and stimulate emerging subsectors. While OARDC must concentrate on tailoring initiatives to target those niches with the greatest promise of economic growth, it must not lose sight of the inherent diversity of agbioscience activity. The challenges that leaders face are the needs to balance initiatives between solidifying core areas within the agbiosciences and to promote new innovative industrial technologies that promise continual economic growth.

Purpose and Methodology for the Agbioscience Core Competency Assessment

INTRODUCTION

In this section, Battelle begins to examine the agbioscience research core competencies that will drive future economic growth. One of the requirements for understanding the potential for agbioscience development is a solid understanding of the existing agbioscience-related research competencies within OSU, and specifically OARDC, upon which future agbioscience advances may be made. Across the nation, each state's major agricultural research institutions have their own particular core research strengths and focus areas, and, as will be shown, Ohio is no exception.

Without a strong agbioscience research foundation, it is difficult for any state or region to initiate or sustain major industry development related to the agbiosciences. Universities are the primary leaders in basic and applied agbioscience research. Increasingly, universities are bringing enabling technologies to the fore, helping to advance agbioscience-related applications in areas such as imaging, analytical instrumentation, processing technology, diagnostics, therapeutics, and materials science. Research centers are not only essential to the basic research discoveries that generate product leads for agbioscience companies; they also contribute to an environment in which these agbioscience companies can flourish. University research centers can be a key asset for the agbioscience industry in bridging the gap between basic and applied research.

In the agbiosciences, R&D impacts an unusually large and vertically integrated suite of industries, incorporating technologies to enhance agricultural productivity (fertilizers, farm management software, precision agriculture technologies, agricultural machinery, etc.), the production of agricultural commodities (farming), and high-value niche agricultural products (such as biopharmaceuticals and chemical compounds via plant pathways), and the processing of agricultural commodities into value-added products (such as foods, oils, chemicals, fuels, pharmaceuticals, nutraceuticals, biomaterials, etc.).

Looking forward, the agbiosciences offer enormous potential for linking basic research innovations with new market opportunities. Among the major potential breakthrough areas are the following:

Plant Biotechnology

- Pest- and disease-resistant crops
- Increased crop yield and desirable quality characteristics
- Lengthened growing seasons via cold resistance or reduced light tolerance
- Enhanced shape, texture, flavor, and processability characteristics
- Technologies to reduce the required application of fungicides, herbicides, and insecticides

Animal Biotechnology

- New approaches to animal disease diagnostics, prevention, and treatment
- Increased food animal meat yield and desirable quality characteristics
- Improved technologies for food preservation and the prevention of spoilage and food-borne diseases
- Genetic resources for development of biologics, drugs, and pharmaceuticals for human and veterinary applications

Plant Biotechnology

- Functional foods and nutraceuticals
- Genetic resources for development of biologics, drugs, and pharmaceuticals
- Genetic resource (germplasm) preservation and storage technologies
- Development of biosensors for industrial and commercial applications
- "Biopharming" and the production of novel and useful chemicals via plant pathways
- Development of sustainable bio-based fuels
- Development of advanced biomaterials for use in construction and other industrial applications
- Development of degradable plastics from plant starch, protein, and fermentation-produced monomers
- Bioremediation and environmental protection via plants
- Enhanced biosecurity

Animal Biotechnology

- Xenotransplantation and tissue engineering, providing organs and tissue for human medical applications via animal pathways
- Development of engineered species, such as customized predator insects, to control pests and diseases
- Development of biosensors for industrial and commercial applications
- Bioremediation and environmental protection via microbial pathways
- The use of animal waste and by-products as renewable energy and chemical production resources
- Enhanced biosecurity
- The novel application of animal and plant genetic resources to new technologies such as biological computing

Because research is the driving force behind agbioscience innovation and commercialization, it is imperative that OARDC's decisions regarding science and technology policy be built upon a formal understanding of their research core competencies. To develop a profile of OSU's and OARDC's agbioscience core competencies for Ohio, Battelle has followed a proven set of actions used with success in previous agbioscience evaluation projects.

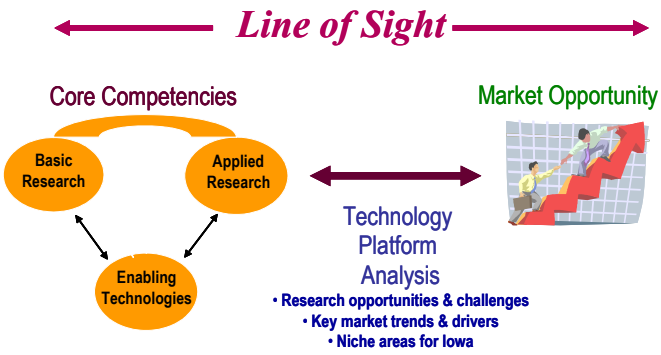
Methodological Approach to Assessing OARDC's Core Research Competencies

Successful translation of agbioscience research strengths into economic development opportunities requires the recognition of "market-driven" processes. The traditional model of commercialization assumes a "research-driven" approach. This research-driven commercialization process proceeds in a pipeline fashion, from basic research to a major scientific breakthrough, applied research, product development, and industrial manufacturing and marketing. The research-driven approach is too divorced from commercialization and product development needs and has uncertain economic value. The market-driven approach recognizes that commercialization is a highly interactive process involving close ties

between research activities and business development activities. Success depends, as the Council on Competitiveness points out, "on a team effort that includes carefully focused research, design for manufacturing, attention to quality and continuous market feedback."[13]

Figure 5 shows that components of core competencies can bring together basic research, enabling technologies, and applied research with a "line of sight" that moves seamlessly to address clinical needs and market opportunities and form robust technology platforms. Core competency areas that lack this linkage and connection to needs and market opportunities offer more limited development.

Figure 5: Line of Sight



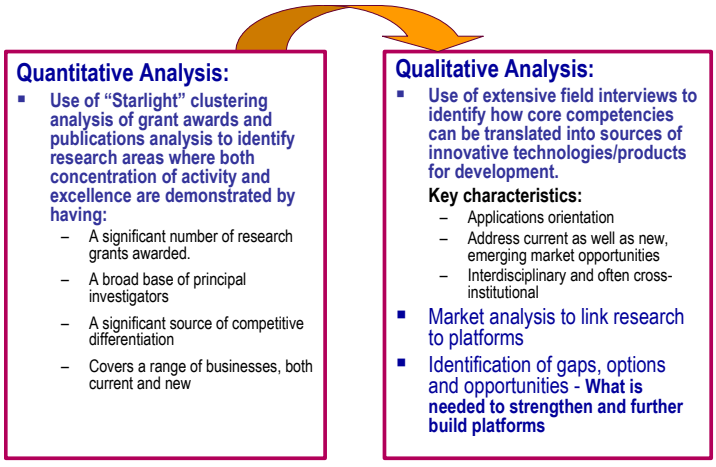
No one single source of information serves to identify core research focus areas at universities and nonprofit research institutions. Rather, a variety of integrated and complementary analyses are required to help identify an institution's current position and areas of focus that may lead or contribute to the state's future growth.

In identifying core research focus areas in the agbiosciences, the objective is to identify those fields with a critical mass of ongoing activity and measures of excellence. Other fields of agbioscience strength may be present within OSU and OARDC, but in relatively limited pockets and so offering limited opportunities.

Core research focus areas are identified using both quantitative and qualitative methods (Figure 6):

- Quantitative analysis uses statistical information on extramural grants, publications, and patent activities—as well as Battelle's proprietary software tool "Starlight" to identify research clusters—to develop an understanding of the trends and characteristics of bioscience research within OARDC and OSU.
- Qualitative analysis includes extensive field interviews with key administrators, scientists, and researchers at OSU and OARDC.

Figure 6. Quantitative/Qualitative Analyses



The questions that are explored in the core competency assessment focus on the following:

- What is OARDC's and OSU's overall volume of agbioscience research; and what trends, positive or negative, are being demonstrated?

[13] Council on Competitiveness, *Picking Up the Pace: The Commercial Challenge to American Innovation* (Washington, DC: Council on Competitiveness), pp. 9-10.

- In which fields of agbioscience and related activities are OSU and OARDC receiving significant levels of funding, especially sources such as the U.S. Department of Agriculture (USDA), National Science Foundation (NSF), etc.?
- In what agbioscience and related fields do OSU and OARDC demonstrate a substantive and influential record of publication?
- What areas of agbioscience and related fields do OSU and OARDC self-identify as core competencies?
- Based on quantitatively and qualitatively identified core competencies, what development opportunities can be identified for the near term (the next five years) for growing the agbiosciences and related industries and technologies in Ohio?
- Which agbioscience core competencies show the most promise for becoming centers of growth for incorporation into Ohio's statewide technology and economic development policy?
- Which core areas of agbioscience focus require additional investment to realize their development potential, and what might the levels of required investment be?

Evaluating the answers to these questions provides insights into the Ohio agbioscience research base within OSU and OARDC and draws implications of how these research strengths may best intersect with the state's industry base, economic competitiveness factors, and market trends.

Quantitative Assessment of OARDC's Core Competencies: Trends and Developments

In this section, core competencies are analyzed quantitatively by examining the specific areas of agbioscience and related activities at OSU/OARDC that are receiving extramural funding. The volume of funding is considered an indicator of the agbioscience fields in which OSU and OARDC are most active. NSF and USDA data primarily are used for this analysis.

In addition to examining agbioscience funding levels, this assessment also analyzed ISI citations data—a source providing detail on research "output" in terms of number of papers published (by discipline) and the average number of citations received per paper. ISI maintains a detailed database of U.S. scientific papers and associated citations, allowing OSU's paper output in agbiosciences and related disciplines to be compared with national norms and indexed for relative impact. Using ISI data, the relative concentration of individual agbioscience fields within institutions can be calculated against national norms. The proprietary Battelle Starlight™ cluster analysis tool for mining research abstract information also is used.

The various statistical sources were used to derive an overview of research core competencies and to provide a more specific description of the character of the agbioscience expertise at OSU and OARDC. A research area is considered to be a core competency area when it has the following:

- A significant number of agbioscience-related research grants awarded through rigorous peer-review processes such as those at NSF and USDA.
- A broad base of principal investigators, along with prominent agbioscience researchers who hold multiple peer-review grants.
- A substantial level and impact of publications.
- An observable position shown in the Starlight™ cluster analysis.

Core Competency Areas Suggested by External Funding Data

In terms of total university-based R&D activity, OSU stands 19th in the nation, with $390.7 million in total research funding (as recorded by the NSF for 2001, Table 4). This level of R&D at OSU outpaces all other universities within the State of Ohio.

Furthermore, OSU historically has performed relatively well in terms of academic life science R&D. In 2001, 50.5 percent ($197.4 million) of the $390.7 million in total OSU-based research was within the life sciences—this $197.4 million research performance placed OSU 29th in the nation. It also is interesting to note that OSU has sustained a strong position in multiple areas of life science R&D, with a ranking of

- 27th in the nation in "agricultural sciences" ($40.8 million)
- 32nd in "biological sciences" ($58.4 million)
- 12th in "other life sciences" ($16.8 million).

Table 4: OSU Agbioscience-Related Funding

Total R&D Expenditures at OSU, FY 2001 (Rank of OSU vs. Other Ohio Schools and vs. All Other Surveyed U.S. Institutions) Nominal (2001) dollars (000s)					
	OSU R&D, FY 2001	% OH	OH Rank	% U.S.	U.S. Rank
Total Of All Academic Disciplines	**$390,652**	**39.2%**	**1**	**1.2%**	**19**
Life Sciences Total	**$197,406**	**35.1%**	**1**	**1.0%**	**29**
Agricultural Sciences	$40,794	99.1%	1	1.8%	27
Biological Sciences	$58,416	30.6%	1	1.0%	32
Medical Sciences	$81,376	26.7%	3	0.8%	49
Other Life Sciences	$16,820	65.4%	1	2.2%	12
Other Critical Sciences					
Chemical Engineering	$6,441	29.7%	1	1.6%	17
Chemistry	$12,174	33.1%	1	1.2%	19

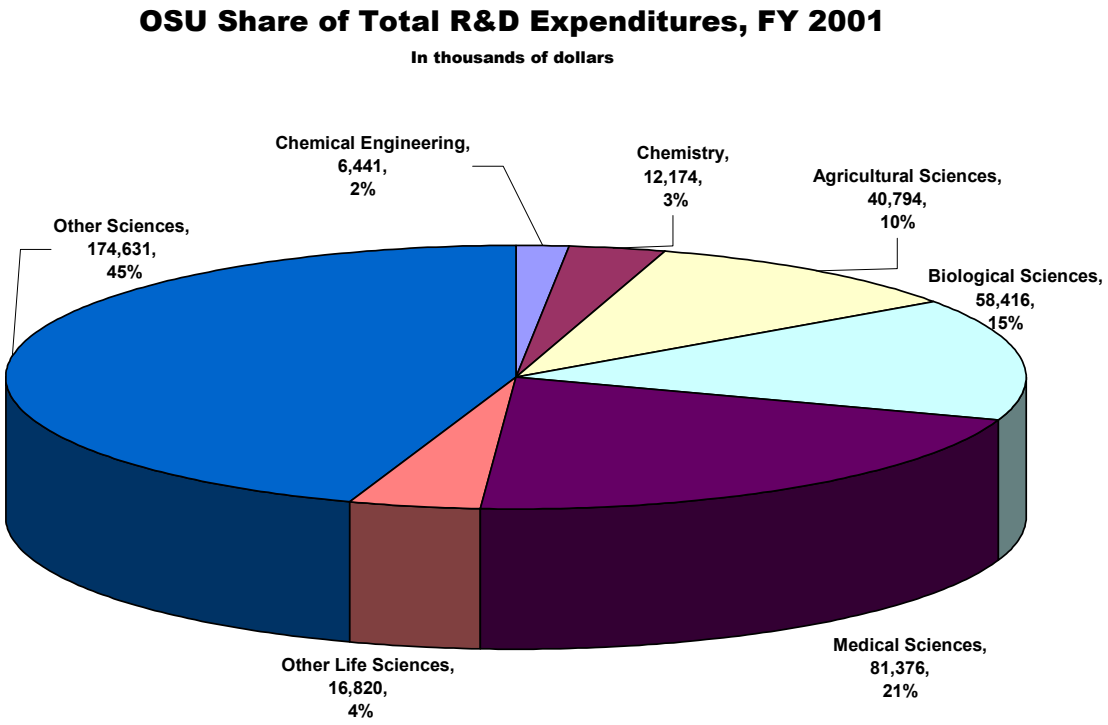
Source: National Science Foundation, Survey of Research and Development Expenditures at Universities and Colleges, *and Battelle calculations, FY 2001.*

It is important to note two additional items. First, for the purposes of this agbioscience analysis, it must be pointed out that OSU accounts for 99.1 percent of all agricultural sciences research conducted in the State of Ohio. This is obviously due in large part to OSU's designation as the state's land grant institution; however, in other areas of life science research, OSU is capturing only approximately one-third of the total funding to the state. Secondly, in two additional areas important to the agbioscience research base, chemical engineering and chemistry, OSU ranks 17th and 19th in the nation, respectively. This indicates that OSU's core basic science research base, upon which its agbioscience research is conducted, is equally strong.

The three pie charts in Figure 7 illustrate that Ohio is similar to the nation as a whole in the percentages of agbioscience-related R&D expenditures, except in agricultural sciences where Ohio has a smaller-than-average concentration (4.1 percent compared with 7.1 percent nationally). However, when OSU is compared with the nation, quite a few variations are noted; in particular, OSU has a larger average concentration in the agricultural sciences (10.1 percent versus 7.1 percent nationally).

It should be noted that, while OSU has performed comparatively well in agbioscience research when compared with the nation, its share of U.S. academic agricultural science R&D funds has experienced a decline over the last several years for which data is available. Figure 8 illustrates that while OSU's agricultural federal research dollars were increasing during this time period, it was not keeping pace with national growth. This could possibly indicate that Ohio is not as competitive as other state's in receiving federal grant dollars, possibly due to its lack of investments in research infrastructure, key faculty hires, and support for agricultural research.

Figure 7: Share of Agbioscience-Related R&D for OSU, Ohio, and the United States



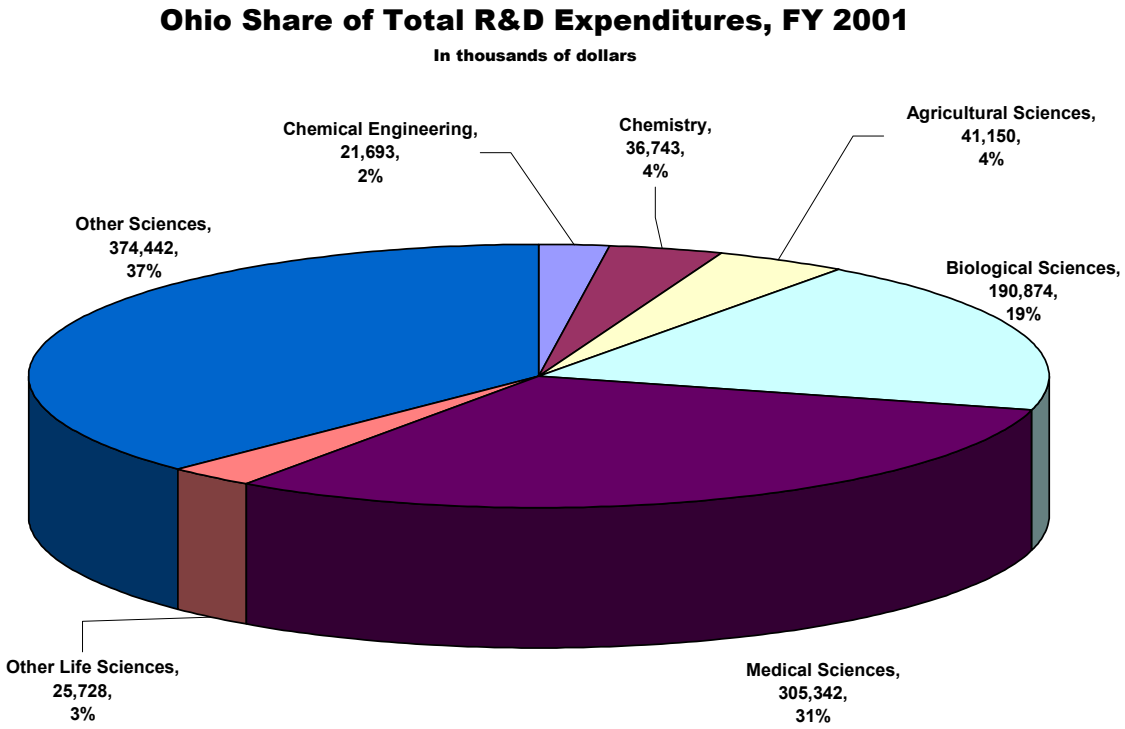


Figure 7: Share of Agbioscience-Related R&D for OSU, Ohio, and the United States (continued)

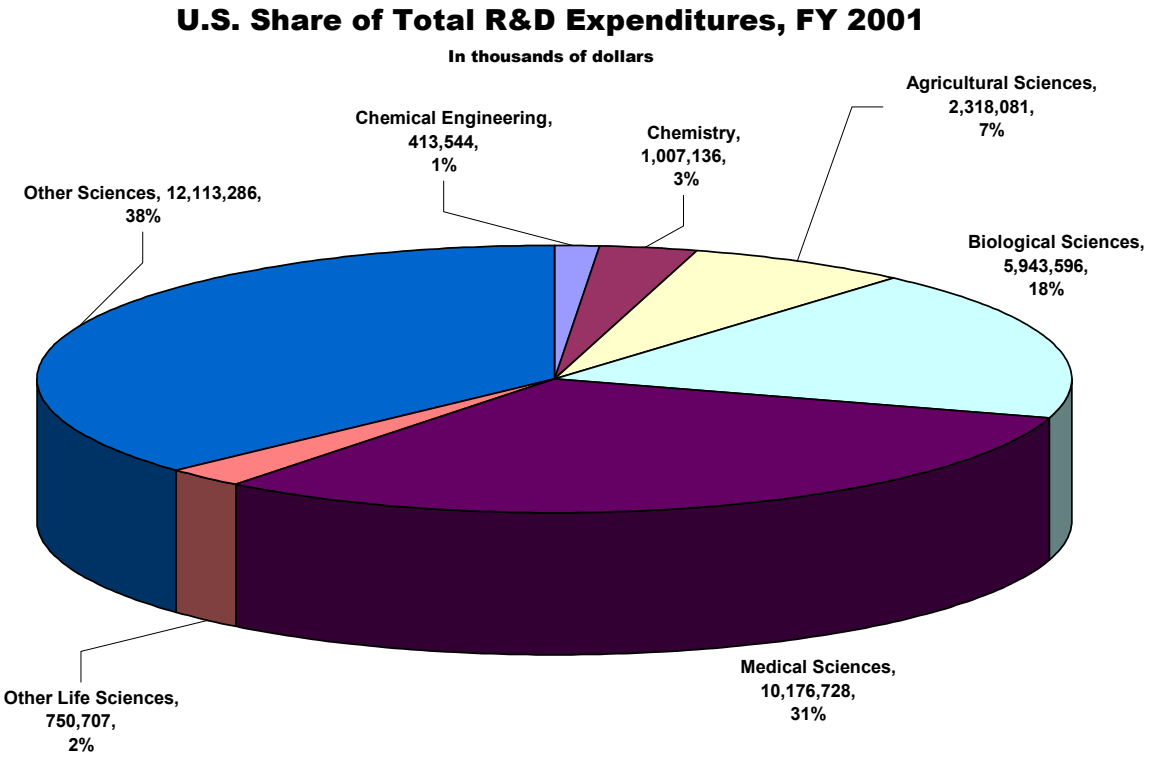
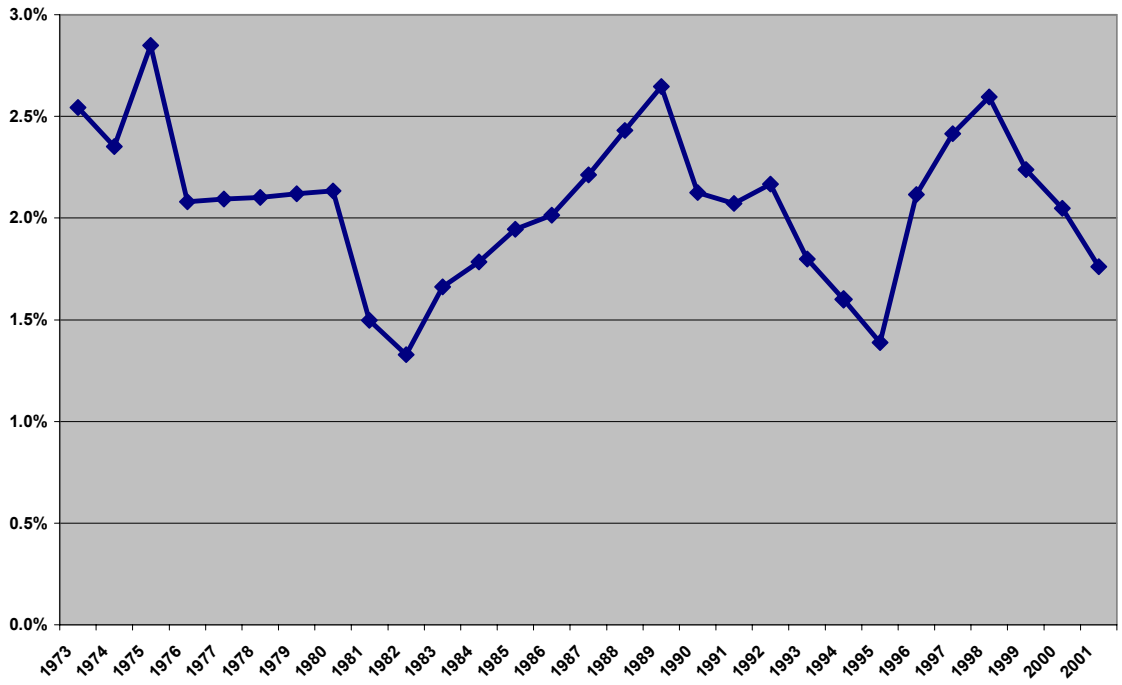


Figure 8: Agricultural Science R&D at OSU as a Percentage of U.S. Agricultural Science R&D



Another way of examining this issue is by studying key data relating to OSU's recent performance in the agricultural sciences, which is highlighted in Table 5. The data show that OSU has a greater concentration of its total academic R&D in the agricultural sciences than Ohio or the nation. However, the data also illustrate that, while OSU's percentage share of agricultural research is above the norm for both Ohio and the nation, OSU and Ohio are not keeping pace in growing their agricultural science research base. OSU does have a larger percentage of USDA funding as a percentage of total federal obligations, 15.6 percent versus 5.3 percent, respectively. However, the agricultural science academic R&D spending per capita in Ohio is considerably below the U.S. average ($3.61 versus $8.12). In addition, OSU's comparative concentration in the agricultural sciences will decline if its growth in R&D funding does not keep pace with the growth rate of the nation.

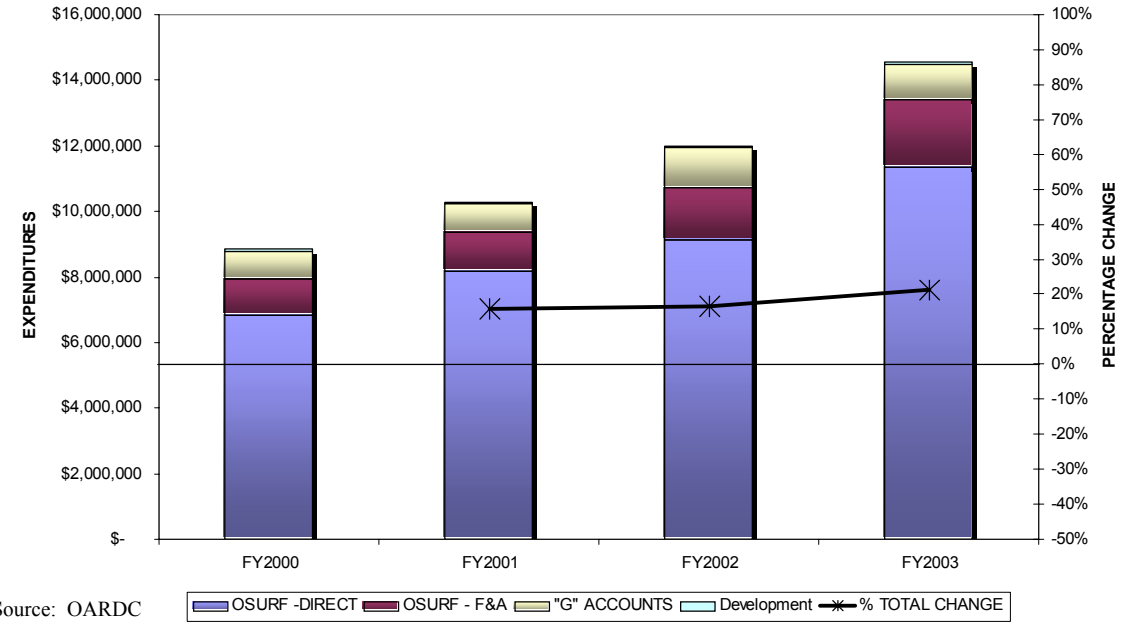
Table 5: Recent Agricultural Science Performance

Metric	Ohio State University	Ohio Total	United States
Total Academic R&D, FY 2001	$390,652,000	$995,972,000	$32,723,078,000
Total Agricultural Sciences R&D, FY 2001	$40,794,000	$41,150,000	$2,318,081,000
Agricultural Sciences as a % of Total Academic R&D	10.4%	4.1%	7.1%
Academic Agricultural Sciences R&D Per Capita, FY 2001	N/A	$3.61	$8.12
USDA Obligations for S&E R&D, FY 2001	$28,167,000	$31,724,000	$1,199,187,000
USDA as a % of Total Federal Obligations for S&E R&D, FY 2001	15.6%	5.1%	5.3%
% Increase in Academic Agricultural Sciences R&D, FY'97-01	-14.1%	-13.4%	17.9%

Sources: National Science Foundation, Survey of Research and Development Expenditures at Universities and Colleges, *and Battelle calculations, FY 2001; United States Census Bureau estimates, FY 2002.*

Finally, it is important to note that over the last four years OARDC has experienced a significant increase in research dollar expenditures, an increase of approximately 20 percent each year. This has occurred at a time when state funding has been in decline. This rapid growth can be attributed to key hires and investments that have attracted and leveraged federal and other resource investments. It is believed that this trend line should continue as additional investments are made. See Figure 9.

Figure 9: FAES Expenditures, FY2000-2003



Source: OARDC

CORE COMPETENCY AREAS SUGGESTED BY ISI CITATIONS DATA

ISI provides specific insight regarding the volume of publications produced by departments and the influence, in terms of citations, that each department's work is having within its field. ISI data were accessed for 1997 through 2001. In determining areas of strength within the OSU/OARDC agbioscience research complex, the following ISI index parameters regarding bioscience and related fields were established:

- During the time period under study, the department of the university must have published 100+ papers in a field.
- The publication concentration ratio must be 1.2 or higher as an indication of a concentration of effort in the area within the department. The ratio measures the degree of concentration in a field within a department versus the U.S. average. A ratio of 1.2 indicates that the institution has a 20+ percent degree of concentration in an area versus the average for all U.S. institutions.
- Citation quotients are a measure of the concentration of a particular field at an institution relative to all U.S. institutions. The citation quotient consists of the ratio of the total citations in a particular field at an institution versus the total number of citations at the institution and the ratio of total citations in the same field at all US institutions versus the total number of citations at all US institutions. A citation quotient greater than 1.0 indicates that the institution is relatively *concentrated* in the particular field, whereas a citation quotient less than 1.0 signifies relative under-representation. Citation quotients are used to report institutional concentrations relative to the United States. The minimum concentration threshold for declaring *specialization* in a particular field is a matter of judgment and varies somewhat, however, we define a specialization here as having a citation quotient of 1.2 or greater.

The ISI data includes research conducted within OARDC but also research in all OSU colleges, schools, and departments. Table 6 illustrates all bioscience and related basic science and engineering disciplines at OSU that meet the parameters. Under this very broad definition, much is included that falls under human medicine and areas of scientific inquiry that are not agbioscience. However, since much advanced work in science and technology crosses disciplinary boundaries, it is important to acknowledge OSU's wide-ranging life science and associated subject expertise. Table 7 focuses on OSU citations in those fields most likely to directly or indirectly incorporate agbioscience R&D.

Table 6: ISI Citations Data Sorted by Number of Papers Published at OSU Bioscience, Basic Science, and Engineering Disciplines

Field	Number of Papers	Publication Concentration Ratio
Physics	828	1.66
Veterinary Med/Animal Health	545	4.11
Materials Science and Engineering	421	1.40
Environment/Ecology	393	1.02
Plant Sciences	364	1.60
Animal Sciences	305	1.76
Organic Chemistry/Polymer Science	293	1.26
Mechanical Engineering	284	1.60

Agriculture/Agronomy	203	2.43
Food Science/Nutrition	201	2.00
Entomology/Pest Control	162	1.73
General and Internal Medicine	158	0.67
AI, Robotics, and Auto Control	146	1.46
Dentistry/Oral Surgery and Med	137	1.87
Neurology	136	0.79
Animal and Plant Sciences	132	1.44
Pharmacology/Toxicology	128	1.48
Info Technology and Commun Systems	126	1.89

Table 7: ISI Citations Data Sorted by Number of Papers Published at OSU - Only Agbioscience Fields

Field	Number of Papers	Citation Quotient	Publication Concentration Ratio	Citation Intensity National Rank
Veterinary Med/Animal Health	545	64.45	4.11	3
Environment/Ecology	393	17.10	1.02	9
Plant Sciences	364	26.80	1.60	9
Animal Sciences	305	23.03	1.76	6
Agriculture/Agronomy	203	39.20	2.43	7
Food Science/Nutrition	201	28.77	2.00	5
Entomology/Pest Control	162	17.35	1.73	8
Animal and Plant Sciences	132	28.89	1.44	10

As the numbers indicate, OSU performs quite well in terms of its publication concentration ratio for the specific agbioscience fields. However, while publication concentrations can indicate the volume of papers produced, an even more telling metric is the citation quotient and its relative national ranking. In terms of citation quotients, OSU performs on a magnitude of 17 to 64 times the national average, indicating that its publications are of extremely high quality and are frequently cited. Finally, OSU displays its national leadership in agricultural research endeavors by ranking in the top ten in terms of its citation intensity when compared to all other U.S. academic institutions. Again, this is a measure of not only the volume of research publications but also the comparative quality.

CORE COMPETENCY AREAS SUGGESTED BY STARLIGHT™ CLUSTER ANALYSIS

Battelle, through its research at the Pacific Northwest National Laboratory, has developed proprietary pattern recognition and clustering software that provides unique insight into research strength areas. The clustering tool, known as Starlight™, uses pattern recognition algorithms to cluster research fields into grouped strength areas. Starlight™ is valuable because it allows free association of words and phrases, rather than forcing clustering on preselected key words—thus, there is no "a priori" bias to the clusters identified.

Battelle has performed the OSU/OARDC Starlight™ analysis on research abstract data. The clustering analysis involves the following steps (Figure 10):

- Step 1—Content Development: A data-set is developed with sufficient descriptive content. Starlight™ cannot work with only titles or single-sentence descriptions.

Figure 10. *Method for Using Starlight Cluster Analysis*

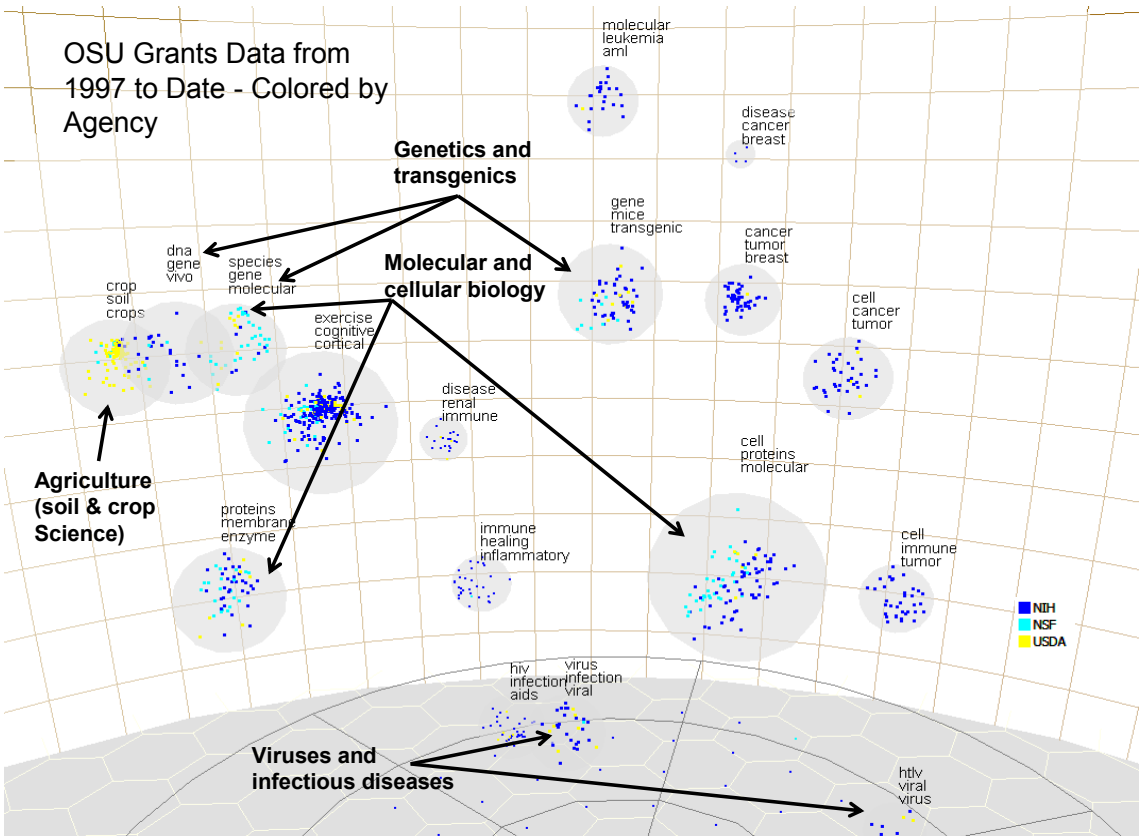
- Step 2—Pattern Recognition: The analysis generates clusters where grant activity has apparent relationships and produces a series of words to describe and link these cluster areas.
- Step 3—Interpretation and Grouping by Expert Review: An experienced research analyst culls through the cluster items and interprets and explains the types of technologies and specific activities represented.

The Ohio grants analysis dataset contained detailed abstract information for 1,086 grants, including grant data from the following agencies for FY 1997 to November 2003:

- National Institutes of Health (NIH)—737 grants
- USDA—210 grants
- NSF—139 grants (only bio/agriculture-oriented grants).

Starlight™ output is provided to the analyst in both graphical and spreadsheet table formats. This allows for visualization of key cluster areas and deeper investigation of the actual grants or patent information contained within each apparent cluster. Figure 11 illustrates the resulting graphic for grants activity, with grants included from the NIH, NSF, and USDA federal funding sources.

Figure 11 Starlight Clusters—Grant Data by Agency



The grants cluster analysis provides insight into key bioscience focus areas at OSU (including human biomedical sciences) and key elements of bioscience that are agbioscience or related to agbioscience. The cluster results highlight several areas of research strength in and related to the agbiosciences at OSU.

The Starlight™ data reveal four macro-cluster areas in which agbioscience is a major R&D component at OSU:

- Genetics and transgenics
- Molecular and cellular biology
- Agriculture (soil and crop science)
- Viruses and infectious diseases.

SUMMARY OF CORE COMPETENCY AREAS SUGGESTED BY QUANTITATIVE ANALYSIS

The quantitative data sources (grants data, ISI citations data, and cluster analysis data) provide considerable insight into the R&D strengths of OSU and OARDC in the agbiosciences and related fields. Several broad themes are contained within these data that serve as "direction finders" to the University's agbioscience core competencies. Among the broadly based R&D core focus areas are the following:

Agricultural Sciences—In which OSU is the key player in the state, with 99.1 percent of all R&D funding for agricultural sciences in Ohio coming to OSU. The agricultural sciences field at OSU as a percentage of total OSU academic R&D is higher at OSU than for the nation as a whole. Indeed, the USDA is a far more prominent funder in Ohio (by a factor of almost 3) than it is for the nation as a whole.

Within this over-arching category of agricultural sciences, the quantitative data indicate that OSU and OARDC are particularly well positioned in

- **Agriculture and Agronomy, including Soil and Crop Science**
- **Food Science and Nutrition**
- **Plant Sciences**
- **Animal Sciences**
- **Genetics and Transgenics**
- **Molecular and Cellular Biology**
- **Animal Viruses and Infectious Diseases**
- **Veterinary Medicine and Animal Health.**

The core focus areas resulting from the quantitative analysis are used to

- Direct the focus of field interviews for additional investigation.
- Inform the identification of core competencies and technology platforms.

The following section details the findings from the qualitative interview research conducted within OSU and OARDC. Both the quantitative and qualitative findings are then evaluated to determine core technology platforms upon which agbioscience development may be built in Ohio.

Qualitative Assessment of OARDC's Core Competencies: Overview of Field Interviews

INTERVIEWS SUGGEST OARDC STRENGTH AREAS

The analysis of USDA, NSF, ISI, and other published data help set the context for understanding where OARDC/OSU's core competencies in agbioscience research are focused. To further investigate these fields and deepen our understanding of the core agbioscience focus areas at OSU, extensive interviews were conducted with administrators, faculty, and staff at OARDC and the University. These interviews are essential in developing an understanding of how the data on publications and grant awards translate into on-the-ground focus areas.

Interviews were held with key OARDC research scientists and faculty in Wooster and Columbus. The interviews, for the most part, served to confirm the areas of specialization at OSU and OARDC identified in the quantitative analysis. They also, however, highlighted several new and emerging areas of R&D focus and some key theme areas that were not readily apparent within the quantitative datasets. One of the challenges in using quantitative data is that, because the scientific enterprise changes rapidly, peer review systems—whether used for federal grant awards, citation analysis, or in reputation rankings—tend to lag the emergence of new fields of inquiry as well as the recognition of younger and new scientific talent. One objective of the qualitative interviews was to ensure that emerging areas, faculty, and fields of inquiry were captured.

The analysis synthesized the core content of the field interviews to highlight key areas of strength and focus observed. Both these qualitative interviews and the quantitative research are of substantial importance in determining core competencies—they go hand-in-hand in answering these questions:

- Where is OARDC and OSU heading in terms of building upon and leveraging their core agbioscience strengths and in terms of developing and enhancing new and emerging areas of bioscience focus?
- What is the current pipeline of agbioscience R&D activity taking place within OSU and OARDC?
- What areas of agbioscience are generating commercial opportunities for Ohio in terms of patents and intellectual property (IP)?

The field interviews provide important information relevant to each of these three questions, but they are most important in providing an in-depth understanding of current and emerging R&D strengths and opportunities.

Tables 8 through 14 synthesize interview and secondary data to identify core focus areas in agbiosciences at OARDC.

Table 8: OARDC Strength Areas: Food Development, Processing, and Safety

	Food Development, Processing, and Safety
Field Definition	This includes activity targeting the development of new food products, processing technologies, and technologies for the promotion of food safety.

Interview Identified Strengths	• OARDC researchers are active in R&D related to functional foods—this includes work in
	  ○ Tomatoes
	  ○ Buckwheat
	  ○ Soybeans.
	Functional food projects are examining food content that leads to functional human health benefits, such as reduced risk of prostate cancer (via lycopene) or reduced cataract incidence (via carotinoids).
	Advanced food processing technologies are a focus of considerable research at OARDC. This includes work in a wide variety of novel areas, including the use of pulsed electrical fields, ohmic heating, and electro-coating (for flavor coatings) as more efficient processing technologies.
	Sterilization and pasteurization technologies for food safety and preservation is another key OARDC thrust. Key areas of R&D in this field include
	  ○ Ozone
	  ○ High-pressure processing
	  ○ Pulsed electrical fields
	  ○ Ohmic heating.
	Food safety is being further promoted via research into rapid detection technologies for identifying food-borne pathogens. OARDC approach uses real-time polymerase chain reaction (PCR) technology, potentially reducing tests to minutes rather than hours.
	Work is ongoing on food quality and specific aspects of taste, texture, color, morphology, and smell.
	New food products are being developed at OARDC, with the most recent example being soybread.

Table 8: OARDC Strength Areas: Food Development, Processing, and Safety (continued)

	Food Development, Processing, and Safety
Supporting Statistics	17 major ongoing research projects, including the following studies: • A Model System for Functional Foods: Tomato Products Containing Soy • Analysis and Properties of Fabricated Food Ingredients and Proteins • Carotenoids and Age-Related Cataracts • Inactivation of Enzymes in Food Using High-Pressure Processing (HPP) • Investigations of Taste, Smell, and Flavor • Mechanism and Prevention of Reversion Flavor Formation in Soybean Oil • Microbial Metabolic Coordination and Food Safety • Novel Food Processing Technologies • Powder Coating of Foods • Quality Of Milk and Shelf Life • Supra-molecular and Molecular Characterization of Food Components • Use of Ozone to Enhance the Safety of Produce • Antioxidants, Oxidative Stress Cell Signal and Diabetes • Bioavailability of Lycopene and Isoflavones from Tomato Products Containing Soy • Design and Evaluation of Food Safety Education for High Risk Groups • Developing Evaluation Instruments for Consumer Food Safety Education • Selenium Nutrition and the Hormone Dependent Cancers of the Breast and Prostate.
Development Potentials	• Functional foods • Value-added foods • Nutraceuticals • Processing and sterilization/pasteurization technologies • Food safety systems and technologies
Key Departments	• Food Science and Technology • Human Ecology • Food Animal Health Research Program

Table 9: OARDC Strength Areas: Food Animal Improvement

Food Animal Improvement	
Field Definition	• This includes genetic and traditional breeding techniques targeted at enhancing desirable characteristics of livestock, poultry, and other food animals.

Interview Identified Strengths	• The Department of Animal Sciences has laboratories in Columbus and Wooster for conducting major research projects in nutrition, animal breeding, genetics, and physiology research. The laboratories in Wooster are some of the best equipped in the world. These labs are supported by an electron microscopy center, computer center, library, photo lab, and feed mill.
	• OARDC animal sciences research is supported by substantial animal resources. Animal facilities in Wooster include a turkey research farm, dairy facility, beef cattle, and sheep herds. Closer to Columbus, OARDC operates a dairy facility, along with egg-laying flocks located less than a mile from the Columbus campus and horse, sheep, swine, and beef herds also nearby.
	• Key research focus areas related to the improvement of food animal species include
	  ○ Feed and animal nutrition/nutrients
	  ○ Animal reproduction and breeding
	  ○ Animal maturation
	  ○ Genomics and relationship to desirable qualities
	  ○ The expression of environmental toxicants in meat
	  ○ Animal health and physiology.
	• Genetics expertise in the identification of biomarkers for desirable meat marbling and tenderness characteristics is resulting in the development of a new start-up company in Wooster.

Supporting Statistics	36 major ongoing research projects, including: • Alternative Feed Source for Grazing Ruminants and the Impact of Grazing on Surface Water Quality • Association of Fertility With Temporal Changes in Ovarian Function of Domestic Ruminants • Bioavailability of Nutrients For Dairy Cows • Biochemical and Bacteriological Studies Fundamental to the Processing of Meat • Decreasing Age at Puberty in Bulls • Early Maturation of the Endocrine Axis in Heifers • Embryonic Mortality • Enhancement and Expression of Bioactive Milk Proteins • Environmental Toxicants in Cattle: Definition, Pharmacokinetics, and Removal in Foods, Feeds, and Animals • Genetic and Nutritional Factors Affecting Muscle Characteristics and Carcass Value of Beef Cattle • Genetic Improvement of Cattle Using Molecular Genetic Information • Genetics of Growth and Reproduction in the Turkey

Table 9: OARDC Strength Areas: Food Animal Improvement (continued)

Food Animal Improvement	
Supporting Statistics (continued)	• Identification and Characterization of a Myosin Binding Protein-C Domain in the Chicken Skeletal Muscle Myosin Heavy Chain • Improved Grazing Systems for Beef Cattle Production • Improving Utilization of Available Feed Resources to Increase Performance and Profit From Beef Cows • Integration of Quantitative and Molecular Technologies for Genetic Improvement of Pigs • Interpreting Cattle Genomic Data: Biology, Applications, and Outreach • Investigating the Need for Nonessential Amino Acids in Poultry Diets • Management Practices to Enhance Milk Quality and Safety by Reducing Environmental Bovine Mastitis • Management Systems for Improved Decision Making and Profitability of Dairy Herds • Mastitis Resistance to Enhance Dairy Food Safety • Metabolic Relationships in Supply of Nutrients for Lactating Cows • Methods to Increase Reproductive Efficiency in Cattle • Modifying Milk Fat Composition for Improved Manufacturing Qualities and Consumer Acceptability • Molecular Biology of Protein Degradation and Utilization by *Prevotella Ruminicola* • Molecular Mechanisms Regulating Skeletal Muscle Growth and Differentiation • North American Consortium for Genomics of Fibrolytic Ruminal Bacteria • Nutrition and Management of High-Producing Swine • Nutritional Factors Affecting Efficiency of Beef Cattle Production • Nutritional Factors Affecting Growth, Composition of Gain and Muscle Tenderness in Cattle • Reproductive Performance in Domestic Ruminants • Reproductive Performance of Turkeys • Sequencing the *Prevotella Ruminicola* Genome for Functional and Comparative Analyses • Studies in Progression of Atherosclerosis: Role of the Extracellular Matrix Proteoglycan Component • The Effects of Age of Hen on Embryonic Development
Development Potentials	• Improved, higher-value livestock and poultry breeds (faster growth, leaner meat, enhanced marbling and flavor, etc.) • Healthier food animals with enhanced physiologic characteristics (such as increased bone density to support higher meat yield) • Production of transgenic or chimeric animals for research and commercial applications such as xenotransplantation • Production of transgenic animals for the expression of desirable proteins, biochemicals, drugs, and biologics
Key Departments	• Animal Sciences

Table 10: OARDC Strength Areas: Food Animal Health

Food Animal Health	
Field Definition	This includes work in disease diagnostics, prevention, treatment, and management as it relates primarily to livestock and poultry.

Interview Identified Strengths	• The Food Animal Health Research Program, centered at OARDC Wooster campus, focuses its research on the causes, prevention, and control of livestock and poultry disease with major emphasis on economically important infectious diseases of food-producing animals. Primary research focus is on basic and applied aspects of infectious enteric, respiratory, and immunosuppressive diseases of livestock and poultry. Respiratory and enteric diseases are the most frequent causes of economic losses in food animals. OARDC is considered to be a world leader in research on food animal enteric diseases.
	• The enteric disease focus has been a major initiative in food safety research.
	• Broad expertise across vaccines, treatment, and control strategies.
	• Work has resulted in diagnostic agents and reagents and tests—with the faculty holding multiple test and vaccine patents.
	• Deep expertise in corona viruses, with resulting research related to zoonotic diseases, such as severe acute respiratory syndrome (SARS).
	• Growing work in prion diseases, with research being performed on non-invasive tests.
	• Two labs in the Food Animal Health Research Program are now recognized as worldwide reference labs by the OIE, which develops standards for controls, vaccines, and animal import/export.
	• Strong facilities in support of research, including
	  ○ Germfree animal research facility (with resources for housing swine and calves). The only facility in the world for procurement and maintenance of germfree food-producing animals.
	  ○ Pathogen-free poultry flocks, including the world's only pathogen-free turkey flock, and associated isolation facilities.
	• Expertise in microbiology, immunology, pathology, epidemiology, and environmental sciences with studies conducted at the animal, organ, cellular, and molecular levels.
	• Technologies used include tissue culture, embryo inoculation, serological techniques, monoclonal antibodies, nucleic acid probes, PCR, sequencing, immunocytochemistry, electron microscopy, and flow cytometry.

Table 10: OARDC Strength Areas: Food Animal Health (continued)

Food Animal Health	
Supporting Statistics	16 major ongoing research projects, including • Avian Respiratory Diseases: Pathogenesis, Surveillance, Diagnosis and Control • Characterization of Genes Essential for Antigenicity and Pathogenicity of Infectious Bursal Disease • Current and Sporadic Disease Problems in Poultry • Development of Rotavirus DNA Vaccines • Dynamics of *Campylobacter* Transmission on Poultry Farms • Effect of Infectious Bursal Disease on Campylobacter Infection in Chickens • Effects of Nutrition and Waste Management Technologies on Pathogens in Animal Excreta • Enteric and Pneumoenteric Diseases of Ruminants: Prevention, Control, and Food Safety • Enteric Diseases of Swine and Cattle: Prevention, Control, and Food Safety • Evolving Pathogens, Targeted Sequences, and Strategies for Control of Bovine Respiratory Disease • Factors Affecting the Emergence of Quinolone-Resistant *Campylobacter* in Poultry • Genetic and Antigenic Characterization of *Campylobacter* Major Membrane Protein • Pathogenesis of Human Caliciviruses in Gnotobiotic Animals • Porcine Enteric Calicivirus: Molecular Analysis and Synthetic RNA Transcripts • Regional Collaboration on Neoplastic and Immunosuppressive Diseases of Poultry in the Middle East • Understanding Risk Factors to *Cryptosporidium Parvum*. Studies in Gnotobiotic Pigs.
Development Potentials	• Healthier food animals with enhanced economic results (faster growth, leaner meat, etc.) • Reduced disease losses among livestock and poultry flocks • Commercial biomarkers • Commercial diagnostic tests and kits • Vaccines • Disease treatments
Key Departments	Food Animal Health Research Program, Wooster.

Table 11: OARDC Strength Areas: Crop Optimization and Protection

Crop Optimization and Protection	
Field Definition	Work with staple crops (soybeans, corn, wheat), in addition to fruits, berries, and vegetables to promote desirable characteristics in terms of yield and quality and disease, pest, and stress resistance.

Interview Identified Strengths	• Expertise in breeding of varieties and cultivars of food plants best suited to specific growing conditions of Ohio. Examples include
	  ○ Soybeans
	  ○ Corn
	  ○ Wheat
	  ○ Potatoes
	  ○ Berries
	  ○ Forage Crops
	  ○ Vegetables
	  ○ Grapes.
	• Genomic, and traditional breeding, enhancement of plants for disease resistance, pest resistance, and increased resistance to environmental stress (such as cold resistance).
	• Breeding and development of cultivars with desirable value-added characteristics, such as enhanced morphology, color, protein content, texture, and functional characteristics.
	• Approaches to the prevention and eradication of harmful weeds.
	• Evaluation of new crops for introduction to Ohio agriculture.
	• Identification of specific genetic traits within plants that have value and may be sold commercially.
	• Largest impacts in terms of seed and germplasm releases have come in
	  ○ Soybeans
	  ○ Tomatoes
	  ○ Wheat.
	• Substantial expertise in soybean disease resistance, especially *Phytophthora*-resistant varieties.
	• Cargill plant in Sydney, Ohio, is an example of a facility being established to process an OARDC-produced enhanced-value crop (high-protein soybeans). Program expertise in turf grass also has resulted in strong Ohio industry linkages.

Table 11: OARDC Strength Areas: Crop Optimization and Protection (continued)

Crop Optimization and Protection	
Supporting Statistics	72 ongoing research programs. In Horticulture and Crop Science: • AHL Signaling in *Sinorhizobium Meliloti* and the Effects of AHL Signal Mimic Compounds from its Host *Medicago Truncatula* • Performance and Competitive Ability of Turfgrass Cultivars in Blends • Breeding Improved Wheat Cultivars and Germplasm for Ohio • Characterization and Management of Herbicide Resistance in Horseweed (*Conyza Canadensis*) Populations in No-Till Soybeans • Characterizing Weed Population Variability for Improved Weed Management Decision Support Systems to Reduce Herbicide Use • Contribution of Seed Polymorphism to Diverse Adaptation of the Native Invasive Annual, *Ambrosia Trifida* • Controlling Early Growth of Transplants • Delineating the Roles of Phytochrome A and Phytochrome B in Photoperiodic Timing Mechanisms • Developing Land Races Adapted to Ohio Landscapes • Development of New Potato Clones for Environmental and Economical Sustainability in the Northeast • Enology and Viticulture Research to Improve Wine Quality and Production Efficiency • Evaluation of New and Standard Strains of Forage Crops • Genetic Manipulation of Sweet Corn Quality and Stress Resistance • Impact of Athletic Field Stabilization Materials on Biomass Accumulation, Surface Stability, and Playing Quality on Kentucky Bluegrass • Improved Weed Control through Residue Management and Crop Rotation • Improving the Efficiency of Processing Tomato Production: Managing Color Disorders • Increasing the Antioxidant Level in Ohio Berries for Potential Prevention and Intervention of Certain Cancers in Humans • Influence of Cultural Practices, Environment, and Pests on Growth and Development of Apple and Grapevines • Investigating the Feasibility of Agronomic Crops New to Ohio Agriculture • *Lamium Purpureum* and *Heterodera Glycines*: Interaction and Implications for IPM • Marketing and Delivery of Quality Cereals and Oilseeds • Metabolism and Mobilization of Nitrogen and Carbon in Soybean Nodules • Multidisciplinary Evaluation of New Apple Cultivars

Table 11: OARDC Strength Areas: Crop Optimization and Protection (continued)

Crop Optimization and Protection	
Supporting Statistics (continued)	• Ohio Corn Performance Test • Ohio Soft Red Winter Wheat Performance Test • Ohio Soybean Performance Test • Paths of Transition: Strategies for Peri-Urban Organic Farmers • Physiological and Management Factors Affecting Forage Establishment Under Stress • Plant Germplasm and Information Management and Utilization • Plant Signal-Mimic Compounds and Rhizosphere Biology • Plant Transformation and Characterization of Transgenics • Quality Parameters of Fresh Fruit Juice • Quantitative Genetics and Breeding Methodology in Soybeans • Regulation of Flower Senescence by Plant Hormones • Response of Turfgrass Species to Decreasing Light Levels • Rootstock and Interstem Effects on Pome and Stone Fruit Trees • Seed Biology, Technology, and Ecology • Seed Quality and Seedling Establishment of Vegetable Crops • Selection of Promising Fresh Market Vegetable Germplasm for Disease Resistance and Adaptability for Production in Ohio • The Regulatory Role of Sterols in Plant Development • The Role of ATGRR1 in Sugar and Ethylene Signal Transduction • The Role of Ear Type to Corn Interactions with Management and Environmental Factors • Timing of Tillage for Effective Weed Control in Vegetable Crops • Variety Development for New and Existing Production • Challenges Enhancing Partnerships with Multiple Potato Breeding Programs

Table 11: OARDC Strength Areas: Crop Optimization and Protection (continued)

Crop Optimization and Protection	
Supporting Statistics (continued)	In Plant Pathology: • A Signaling Cascade that Regulates HRP Pathogenicity Genes in *Pantoea Spp.* • Biogeography and Site-Specific Management of DAPG-Producing Pseudomonads in Corn and Soybean Fields • Biological Control of Soil- and Residue-Borne Plant Pathogens • Biology and Management of Corn Diseases in Ohio • Characterization of the Microbial Resources and Liabilities of Ohio's Agricultural Soils: Focus on Corn and Soybean Fields • Develop Systemic Resistance Induced Container Media in Plants/Provide Biological Control of Root Rot • Developing Soybean Cyst Nematode Resistant Soybean Varieties with Specific Adaptation to Ohio • Development of Disease Management Strategies for Soybean Pathogens in Ohio • Development, Evaluation, and Implementation of an Integrated Disease Management Program • Epidemiology and Control of Fruit Crop Diseases • Field Testing of Biocontrol Agents Active Against Fusarium Head Blight of Wheat and Barley • Identification and Functional Analysis of Genes Involved in Disease Resistance Response in Rice • Identification of Maize Viruses, Viral Characterization, and Maize Resistant Genotypes • Integrated Control of Forage Crop Diseases • Microbial Ecology and Management of Turfgrass Diseases • Molecular Basis of Nonhost Resistance in Interactions Between Plants and Economically Important Phytophthora • Optimization of Pest, Nutrient, and Water Management Tools for Fresh Market Tomatoes • Persistence of *Heterodera Glycines* and Other Regionally Important Nematodes • Quantifying the Dissemination and Dispersion of Splash-Dispersed Fungal Pathogens of Strawberry • Regulation of Deployment of General Disease Resistance in Soybean

Table 11: OARDC Strength Areas: Crop Optimization and Protection (continued)

Crop Optimization and Protection	
Supporting Statistics (continued)	In Entomology: • A Novel Biological Approach to Manage Plant Parasitic Nematodes in Turfgrass • Building a Biologically Based Approach to Manage Insect and Weed Pests in Turfgrass • Control of Insect Population by Regulation of Dormancy • Developing an Integrated Pest Management System for Insect and Mite Pests in Ohio Vineyards • Development of Integrated Management Strategies for Pests of Vegetable and Fruit Crops • Development of Pest Management Strategies for Forage Alfalfa Persistence • Development of Specific Aster Yellows Phytoplasma Detection Assays • Development, Evaluation, and Safety of Entomopathogens for Control of Arthropod Pests • Dynamic Soybean Insect Management for Emerging Agricultural Technologies and Variable Environments • Dynamic Soybean Pest Management for Evolving Agricultural Technologies and Cropping Systems • Effects and Modes of Action of Vermicomposts on Growth of Field Horticultural Crops • Insect Cold-Hardiness and Diapause: Regulatory Relationships • International Colloquium on Entomopathogenic Nematodes and Symbiotic Bacteria • Longevity and Stress Tolerance of Infective Juvenile Entomopathogenic Nematodes • Pest Management Strategies for Small Fruit • Revitalizing Small and Midsized Farms: Organic Research, Education, and Extension • Soil Management Regimes as Components of IPM Programs for Urban Landscapes • Systems Dynamics of Insect Pest Management in Ohio Vegetable Crops • The Effects and Mode of Action of Vermicomposts on the Growth of Field Horticultural Crops • User-Friendly Decision Tools for Predicting Insect and Weed Phenology
Development Potentials	• Higher value and improved crops • Traits and genes with marketable value • New varieties and transgenic crops with enhanced traits and characteristics • Enhanced food crops and functional foods • Enhanced plants for use as biomass/feedstocks
Key Departments	• Horticulture and Crop Science • Plant Pathology • Entomology

Table 12: OARDC Strength Areas: Ornamental Plant Optimization and Protection

Ornamental Plant Optimization and Protection	
Field Definition	Work with ornamental plants in terms of the promotion of desirable characteristics and disease, pest, and stress resistance. Also includes ornamental plant germplasm preservation and storage. Ornamentals are aesthetically pleasing plants used to enhance the home and landscape.

Interview Identified Strengths	• The nursery and landscape industry has experienced significant growth in Ohio and is now one of the leading crops in the state. Growth is facilitated by OARDC research in potting soils and plant varieties. Ohio ranks among the leading states in ornamental plant production.
	• OARDC in Wooster operates the Secrest Arboretum—an outdoor research laboratory and display garden generating knowledge to advance the understanding, use, and enjoyment of plants in Ohio and the Great Lakes Region. By providing research-based information to enhance the environment, the Arboretum helps scientists, educators, students, producers, landscape architects, and consumers.
	• Horticulture and Crop Science produce the PlantFacts Web site, providing detailed information on ornamentals and landscaping plants to interested parties.
	• The Ohioline by OSU disseminates information to Ohioans on ornamentals, flowers, lawn, and landscaping plants and their care.
	• The Ornamental Plant Germplasm Center (OPGC), located on the OSU Columbus campus, is a cooperative effort involving the University and the Agricultural Research Service of the USDA (with support and leadership from the ornamental plant industry nationwide). The goals of the OPGC are to conserve, assess, and distribute herbaceous ornamental plant germplasm and to develop new techniques for conserving seed and clonally propagated germplasm.
	• The OPGC benefits industry and consumers by preserving unique genetic material essential for present and future crops that
	  ○ Are resistant to pests and disease
	  ○ Require fewer economic inputs
	  ○ Promote consumer-product appeal through expansion of crop diversity in form, color, and fragrance
	  ○ May exhibit biological activity valuable to pharmaceutical, nutraceutical, and agrochemical researchers.

Table 12: OARDC Strength Areas: Ornamental Plant Optimization and Protection (continued)

Ornamental Plant Optimization and Protection	
Supporting Statistics	Multiple research projects within OARDC, including • Ecophysiological Approach to Landscape Plant Selection • Genetic Enhancement of Woody Ornamentals by Hybridization, Selection, and Cell Culture • Technical and Economical Efficiencies of Producing, Marketing, and Managing Landscape Plants • Urban Forest Ecology and Sustainable Landscape Horticulture • Interactions Among Bark Beetles, Pathogens, and Conifers in North American Forests • Developing Useful Control Tactics for Arthropod Pests of Christmas Tree, Nursery, and Landscape Plants • Implementing Insecticidal Nematodes in Nurseries, Greenhouses, and Landscapes
Development Potentials	• Ornamental and landscaping plants of commercial value • Licensable genetic traits and cultivars • Identification of biologically active compounds for use in pharmaceutical, nutraceutical, or chemistry applications • Enhanced attractiveness and sustainability of Ohio and its constituent communities—thereby enhancing quality of life as a commercial location factor.
Key Departments	• Horticulture and Crop Science • Plant Pathology • Entomology

Table 13: OARDC Strength Areas: Agricultural and Biological Engineering

Agricultural and Biological Engineering	
Field Definition	The application of the engineering disciplines to agricultural production, harvesting, and processing. Includes engineering approaches to precision agriculture, waste management, facilities design, etc.

Interview Identified Strengths	• Research focus area within the Department of Food, Agricultural, and Biological Engineering are organized under
	  ○ Mechanical Systems Engineering
	  ○ Soil, Water, Environmental, and Ecological Engineering
	  ○ Biological Engineering
	  ○ Plant and Animal Facilities and Controlled Environmental Engineering
	  ○ Agricultural Systems Operation and Management
	  ○ Food and Processing Engineering.
	• Substantial research being undertaken in precision agriculture and the automation of agricultural and horticultural production environments.
	• Significant research focused on hydroponics, especially in the area of hydroponic tomatoes.
	• Environmental protection and remediation also are a focus within engineering, with work on water/wastewater management, bioremediation technologies, and the Ohio Composting and Manure Management (OCAMM) Program.
	• The Department of Food, Agricultural, and Biological Engineering undergraduate program is ranked 10th in the nation under the "Engineering Specialty: Agricultural" by *U.S. News & World Report*.

Supporting Statistics	Multiple research projects within OARDC, including • Alleviating High-Axle Load Induced Soil Compaction • Automation and Mechanization of Greenhouse and Nursery Systems • Automation-Culture-Environment Systems (ACESYS) for Controlled Environment Bioproduction • Bioremediation, Landfills, and Environmental Quality in Ohio • Control of Precision Application Equipment for Site-Specific Crop Management • Decision Support for Design and Control of Plant Growth Systems • Developing Site-Specific Agricultural Systems in Ohio • Ecosystem Change and Wetland Nutrient Cycling Within Ohio Watersheds • Fluvial Geomorphology and Nutrient Processing in Low-Order Streams in Midwestern Tile-Drained Agricultural Landscapes • Food and Agricultural Sciences National Needs Graduate Fellowship Grants Program • Hydroponic Tomato and Forage Grass Research • Hydroponic Tomato and Related Crop Production • Hydroponic Tomato and Similar Crop Production • Hydroponic Tomato Production • Improvement of Thermal and Alternative Processes for Foods • Integrated Compost Production for Livestock Facilities • Material Characterization of Cereal Biopolymers: Calorimetric, Spectroscopic, and Moisture Sorption

Table 13: OARDC Strength Areas: Agricultural and Biological Engineering (continued)

Agricultural and Biological Engineering	
Supporting Statistics (continued)	• Minimizing Odor and Cost of Composting Processes for Organic Wastes • Moderate Electric Field (MEF) Processing: A Theoretical and Experimental Investigation • Performance of Small Wastewater Treatment Systems in Ohio • Water Management in Controlled Environment Plant Production Systems
Development Potentials	• Agricultural production technology • Agricultural processing technology • Food processing technology • Biomass renewable resource processing technology • Environmental protection and remediation technologies
Key Departments	• Food, Agricultural, and Biological Engineering • School of Natural Resources

Table 14: OARDC Strength Areas: Natural Resource Protection and Sustainability

Natural Resource Protection and Sustainability	
Field Definition	The application of environmental, biological, and engineering sciences to the control of soil erosion, sustaining water quality, pollution prevention and control, contamination remediation, etc.

Interview Identified Strengths	• While OARDC is best known for its production agriculture research, it has a considerable track record in environmental issues, ranging from soil preservation and fertility to pollution prevention and remediation.
	• OARDC scientists are leading cutting-edge research in several key areas:
	  ○ Composting and manure management
	  ○ Water quality, protection, and drainage
	  ○ Carbon sequestration potentials in soil
	  ○ No-tillage and low-tillage farming
	  ○ Land use policy and practices.
	• OARDC's work in environmental sciences ranges from issues of global importance (such as ozone layer protection via carbon sequestration in soils) to highly localized Ohio projects (such as water quality in the South Fork of Sugar Creek).
	• OARDC's work in ornamental plants suited to Ohio, strengthened by the resources of the Secrest Arboretum, has helped horticulturalists, city landscape planners, and amateur gardeners enhance and beautify the Ohio landscape. OARDC's work has contributed to a "green industry" in Ohio, with nursery and landscape operations generating $2.78 billion (an increase of 42.3 percent since 1996), employing more than 96,000 workers, and paying $274.9 million in taxes.
	• As the agbiosciences produce advances in transgenic plants and genetically modified animals, OARDC's expertise in environmental monitoring, pollution prevention, and remediation is going to be increasingly important to maintaining both the growth of these new industries and the preservation and protection of Ohio's existing natural ecosystems.

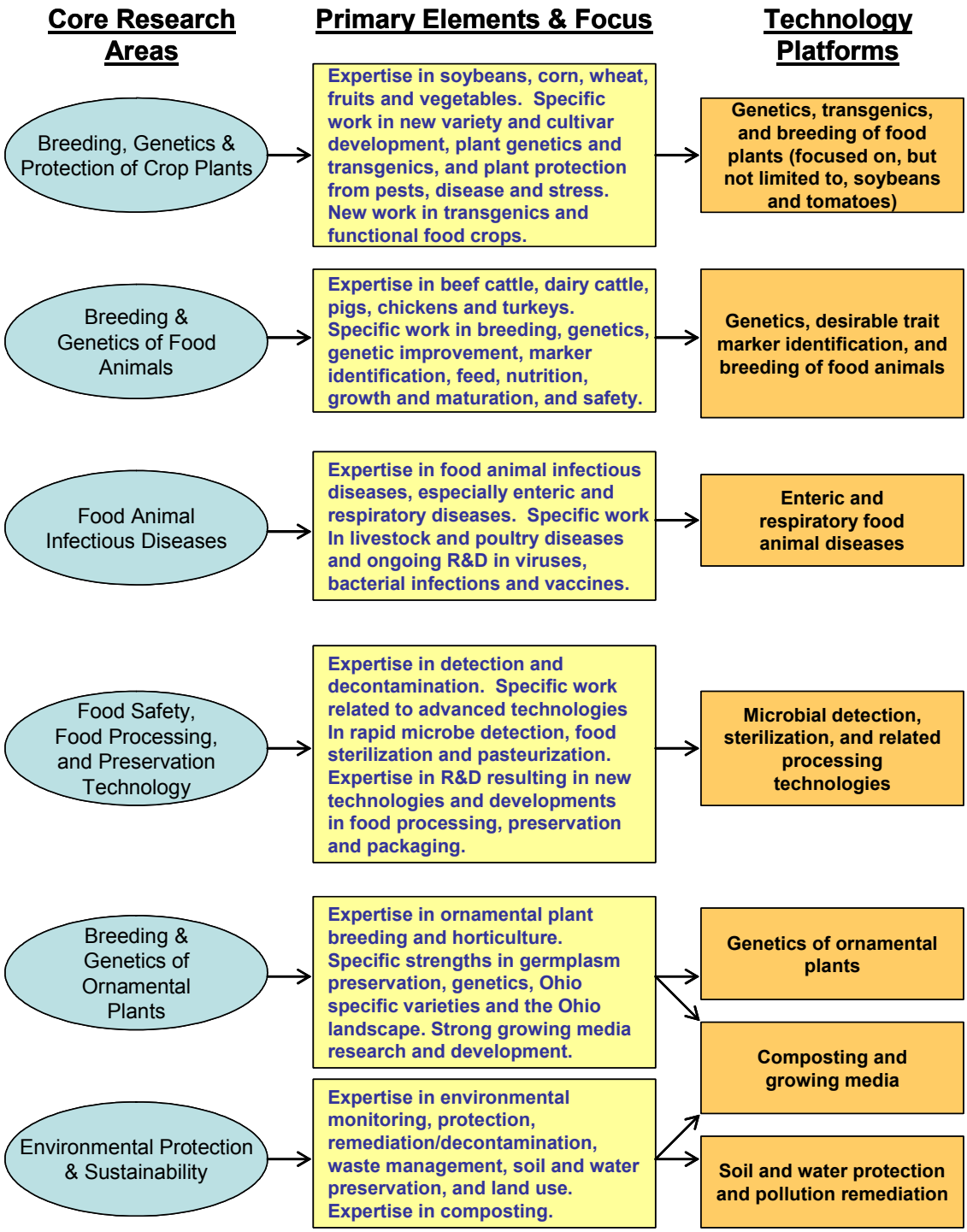
Table 14: OARDC Strength Areas: Natural Resource Protection and Sustainability (continued)

Natural Resource Protection and Sustainability	
Supporting Statistics	28 major ongoing research programs: • Agricultural Pollution Prevention in the Lake Erie Basin: Analysis and Design • An Integrated Examination of the Ecological and Social Value of Natural and Mitigation Wetlands • Aquaculture Research and Development for Ohio • Characterization of Ohio Soils • Chemical Free No-Tillage Crop Production • Chemical Speciation, Chemical Reactivity, and Ecosystem Health • Concepts, Methods, and Tools Used in Ecosystem Planning and Management of Ohio's Forests • Estimating Ecological Functions of Created and Restored Wetlands • Factors Affecting Annual Duck Harvests in Eastern States • Forest Industries Development For Southern Ohio • Improving Sub-Surface Drainage of Clay Soils • Land Use Decisions, Activities, and Policies: U.S. Private and Public Lands • Land Use Effects on Soil Carbon Dynamics in Three Land Resource Regions of the United States • Landscape Ecology of Whitetailed Deer in Agro-Forest Ecosystems: A Cooperative Approach to Support Management • Management of Eroded Soils for Enhancement of Productivity and Environment Quality • Microbial Community Composition, Soil Aggregation, and Carbon Cycling in Agroecosystems • Microbial Contributions to Carbon Sequestration in No-Tillage Agroecosystems • Mineralogy of Ohio Soils, Mine Spoils, and Stream Sediments • Ohio Soil Survey • Phytochemicals and Mechanisms that Influence Growth and Nutrient Utilization in Rainbow Trout • Relating Crop Yield to Crop and Soil Nutrient Element Status • Selection, Establishment, and Maintenance or Trees in Urban Environments • Social Behavior and Social Dilemmas: Implications for Managing Natural Resources • Soil-Plant Relationships in Conservation Tillage Systems • Spatial Integration of Timber and Non-Timber Resource Management Issues • Stand Structural Dynamics of Old-Growth and Mature Forest Ecosystems • The National Atmospheric Deposition Program • The Role of Local and Landscape-Level Anthropogenic Disturbance in Structuring Forest Wildlife Communities
Development Potentials	• Environmental protection technologies • Environmental remediation technologies
Key Departments	• School of Natural Resources • Food, Agricultural, and Biological Engineering

Core Competency Conclusions

Figure 12 shows the results of the quantitative and qualitative evaluations of OARDC's strengths and core competencies.

Figure 12: OARDC's Core Competencies



In an organization with the broad size and scope of OARDC, a wide range of fields with excellent R&D may be observed. The key is to identify the strongest technology platforms upon which agbioscience economic development may be based. Figure 10 illustrates the primary areas in which OARDC has demonstrable expertise and the R&D being conducted within them. The main technology platforms are drawn from these areas of R&D focus and represent the R&D "hubs" from which significant future progress may be expected. **Seven technology platforms at OARDC have significant merit as platforms for future progress, including:**

- ***Genetics, transgenics, and breeding of food plants (focused on, but not limited to, soybeans and tomatoes)***
- ***Genetics, trait marker identification, and associated breeding of food animals***
- ***Enteric and respiratory food animal diseases, including zoonotic diseases***
- ***Food decontamination, sterilization, and associated processing technologies***
- ***Ornamental plant genetics and germplasm "mining" for functional genes useful in the agbiosciences***
- ***Environmental protection and decontamination technologies focused on soil and water***
- ***Composting and advanced potting soil/growing media development.***

On a macro level, the core competencies fall into two overarching theme areas:

- Foods
  - Soybeans and tomatoes
  - Food animals
  - Food animal diseases
  - Food decontamination, sterilization, and processing
- Environment
  - Ornamental plants
  - Environmental protection and decontamination
  - Composting

These technology platforms represent core competencies in which OARDC has a demonstrable track record of R&D success and which show promise for future development. ***Selecting these seven does not mean that OARDC has no other areas of competency, but rather that other areas are smaller or more embryonic in their development and currently form less of a launch platform.***

Table 15 details each of the technology platforms in terms of which quantitative and qualitative data provides the basis for its recommendation.

Table 15: Broadly-Based Core Focus Areas Suggested by Quantitative and Qualitative Data

Core Focus Areas	Extramural Grants	ISI Data (Citations)	Starlight (Cluster)	Field Interviews
Genetics, Transgenics and Breeding of Food Plants	✓	✓	✓	✓
Genetics, Trait Marker Identification, and Associated Breeding of Food Animals	✓	✓	✓	✓
Enteric and Respiratory Food Animal Diseases	✓	✓	✓	✓
Food Decontamination, Sterilization and Associated Processing Technologies	✓			✓
Ornamental Plant Genetics and Germplasm Mining	✓			✓
Environmental Protection and Decontamination Technologies	✓	✓		✓
Advanced Growing Media Development	✓			✓

The next section will delve into these seven technology platforms in greater detail, in terms of their research, market potential, and prioritization based on economic development opportunities.

Positioning OARDC to Leverage its Technology Platforms to Advance Agbioscience in Ohio

CRITERIA FOR NEAR-TERM DEVELOPMENT

The purpose for gaining an understanding of OARDC's research core competencies is to help identify potential areas (technology platforms) in which OARDC may contribute to Ohio agbioscience economic development in the near term. Of particular importance in technology-based economic development is the ability for a state to have specific areas for near-term development within the next 2 to 5 years that can drive not only *research* growth, but also *broader economic growth*. It is these near-term areas for development that provide the best opportunity for the state to become a thriving agbioscience center. They also provide momentum for long-term investments needed to establish broader core competencies in the agbiosciences and sustain more diversified growth in the long term.

To assess near-term development areas, it is helpful to consider areas of primary research focus given the close linkages of research and industry development and the extensive reliance on research for new agbioscience products. But, research alone is not sufficient for ensuring agbioscience development. Rather, a true economic cluster may develop where research intersects with industry growth and development.

Ideally, the criteria for selecting near-term areas of opportunity for development should be

- An area with existing research focus strengths at OARDC
- An area that already has some base of commercial activity emerging or established within the state
- An area with a distinct opportunity to leverage Ohio's comparative advantages to create competitive marketplace advantages
- A field with significant product market potential
- A field that links to, or reinforces, other bioscience and agbioscience strengths and core competencies—thereby helping to enhance other fields as it expands.

For best results, an area should have a "check mark" for each of the criteria to become a near-term development platform. However, other fields and areas should be considered, those that are growing and show potential for significant growth in the future (but may not yet meet all the criteria above). An example of this would be biorenewable resources and the commercial application of biomass—a field that is comparatively new and fast growing, but in which no state has yet developed an unassailable leadership position.

Each of the seven technology platforms are discussed in further detail below in terms of

- OARDC/OSU R&D strengths
- Markets
- Economic development potential.

Then the technology platforms are prioritized, providing guidance on the key opportunities to pursue in the near term.

TECHNOLOGY PLATFORM: GENETICS, TRANSGENICS, AND BREEDING OF FOOD PLANTS (FOCUSED ON, BUT NOT LIMITED TO, SOYBEANS AND TOMATOES)

Field Definition:

This field involves the development of new plant cultivars via traditional breeding and modern transgenics techniques. R&D is conducted to improve soybean and tomato plants in terms of desirable growing characteristics, such as yield enhancement, disease resistance, and stress resistance. Furthermore, R&D is conducted to increase the value of the plant in terms of improved taste, texture, shape, color, and processing characteristics. Increasingly, R&D is working on the functional (health imparting) characteristics of these plants and, in the case of soybeans, on industrial applications of the plant biomass.

Background:

Soybeans—Soybean farming alone represents an $837 million business enterprise for Ohio, with soybeans harvested from 4.7 million acres of Ohio farmland (32 percent of all farmland in the state). Soybeans are valued for their use in animal and human foods and for oil and other chemical constituents. Increasingly, soybeans are being recognized for their functional (health imparting) benefits. Soybean processing also is an important component of the Ohio economy.

Tomatoes—Tomatoes, of both the fresh-market and processing variety, also are an important agricultural product for Ohio. In 2002, the state ranked third in the nation in the production of both categories of tomato fruit, with a total market value of more than $100 million. Tomatoes are valued both as produce for direct consumption and as ingredients for processed foods. As with soy, tomatoes increasingly are being valued for their functional characteristics, such as lycopene content.

OARDC/OSU R&D Strengths:

Soybeans —OARDC's breeding programs and R&D activities are central to the growth and sustainability of the soybean sector in Ohio's economy. Soybean plants are highly sensitive to soil and environmental growing conditions. OARDC has been the leader in developing the high-yield, disease-resistant soybean varieties suited to Ohio's environment.

OARDC R&D in soybeans is particularly strong in the development of

- Disease- and pest-resistant strains, with the resistance increasingly imparted via OARDC's strong programs in plant genetics (gene identification and insertion)
- Soybeans resistant to *Phytophthora* (a devastating fungal water mold)
- High-protein, food-grade soybeans for human consumption (a major export product).

OARDC's strong position in soybean research is made possible by a cluster of experienced and well-published scientists and significant investment in modern technologies (such as molecular market technologies and gene-sequencing equipment). Investment in technology has significantly accelerated R&D discoveries by OARDC faculty and research scientists.

While soybeans currently are a very important crop for Ohio agriculture, international competition (especially from Brazil and Argentina) is threatening the long-term viability of Ohio soybeans as a world market commodity. Advanced OARDC R&D to develop IP-protected varieties of high-yield, high-quality, high-protein soybeans and to pursue the development of soybeans with enhanced functional and

processing characteristics is vital to sustaining long-term growth prospects for this sector of the Ohio economy. Furthermore, OARDC and OSU research strengths in soybeans may be leveraged to produce advances in using soy oils in biodiesel, bioenergy, and other industrial chemical applications.

Tomatoes—OARDC's leading work in tomatoes is guided by the Tomato Genetics and Breeding Program (TGBP). The TGBP researches the genetic basis of field resistance, humid environment adaptation (a characteristic of Ohio's summers), and fruit quality while working on various strategies for crop improvement. The "products" of the team's scientific work are tomato varieties exhibiting enhanced fruit quality and disease resistance. Current research within the TGBP is aimed at further improving the product of Ohio's tomato growers.

Markets:

Soybeans are an important and growing component of North American and Ohio agriculture. In 2001, 177 million metric tons of soybeans were produced globally (with demand increasing at approximately 7 percent per year). Forty-five percent of these soybeans were grown in the United States. Market growth is being driven partly by the use of soybeans as livestock feed, but increasingly by the use of value-added varieties for human consumption and as food ingredients. Much of the interest in soybeans is being driven by their functional food and potential nutraceutical applications.

Functional foods (foods imparting beneficial human health effects) are a fast-growing sector of the bioeconomy and have a worldwide market of $47.6 billion (according to Sloan Trends and Solutions). The U.S. component of functional foods is estimated at more than $18 billion. Soybeans have been the subject of considerable functional research, with functional characteristics being identified such as

- Soy protein, accepted by the U.S. Food and Drug Administration (FDA) as reducing the risk of coronary heart disease
- Free stanols/sterols that reduce the risk of coronary heart disease
- Isoflavones (daidzein, genistein) that may contribute to maintaining healthy bones, brain, and immune function and (for women) maintaining health during menopause.

High-protein soybean varieties offer improved nutrition in both human and livestock diets. These varieties also may qualify for the high-isoflavone and food-grade value-added areas. High-protein soybeans are used to produce soy milk, beverages, baked goods, and puddings, and cheese and meat analogues. They are available as whole beans, full-fat flour, low-fat flour, or soy milk powder.

Major companies such as DuPont and ADM continuously have been enhancing their R&D positions in soy in recent years, based on the opportunities provided by soybeans for functional foods, nutrient supplements, and other applications. Some leading advances in the market include Optimum high-oleic soybeans, which produce oil that is 33 percent lower in saturated fat, has no trans fatty acids, and remains in a liquid form. The high-oleic acid makes the oil more heat-stable for cooking and edible spray applications. Optimum low saturate soybeans produce oil with 50 percent less saturated fat than commodity soybean oil or approximately 8 percent total saturated fats. Optimum low linoleic soybeans produce oil that has a reduced need for hydrogenation, has reduced trans fatty acids, and is more stable than commodity soybean oil.

Tomatoes also are being recognized for functional food benefits, such as

- The carotinoid lycopene, which may contribute to maintaining prostate health and has antioxidant benefits. A diet high in lycopene also may reduce serum lipid levels and the risk of macular degenerative disease and possibly certain lung, bladder, cervical, and gastro-intestinal cancers.

In 2003 more than 116,000 acres of tomatoes were harvested in the United States, an amount that has been comparatively stable for several years. Ohio, however, has seen an increasing return on its tomato production, with its 2002 crop valued at $101 million, up substantially from the circa $40 million in sales realized in the late 1990s.

Economic Development Potential:

Production of soybeans and tomatoes directly account for more than $1 billion in Ohio economic activity, and tomato processing and food processing using tomato ingredients account for much higher dollar volumes. OARDC's R&D, particularly in soybeans but also increasingly in tomatoes, is fundamental to sustaining these sectors and their ongoing economic benefits.

In terms of economic development opportunities, OARDC's work in tomatoes, and especially soybeans, will most likely bring benefits in functional food, phytochemical, and nutraceutical products. OARDC expertise in plant breeding, genetics, and transgenics shows significant potential for generating new and enhanced plant varieties that have added value for these functional applications. The world market for functional foods and nutraceuticals has been growing rapidly; and Ohio has an opportunity to sustain its agriculture base, enhance farm incomes, and develop its processing and functional food/nutraceutical sectors via OARDC-led advances in advanced soybean and tomato varieties.

Recommended Focus:

OARDC research should focus on enhancing the functional food, phytochemical, and nutraceutical components of soybeans. Research to establish the health benefits of soybean phytochemicals and then to increase the expression of these beneficial chemicals in Ohio varieties should be a high priority because of the opportunity to significantly increase the value of the Ohio crop and engender the development of the functional food and nutraceutical sectors in the state. Similarly, research on processing technologies for extracting relevant nutrients and phytochemicals (or maintaining their active expression after food processing) also should be pursued. OARDC's ongoing work in disease and stress resistance and yield enhancement also should be a priority. Tomato-based research along the same lines as that of soybeans also is likely to reap economic rewards for the state, but at a lower overall volume than that realized by soybeans.

Technology Platform: Genetics, Trait Marker Identification, and Associated Breeding of Food Animals

Field Definition:

This field involves the improvement of food animal species through the identification and expression of desirable, value-enhancing traits. R&D is conducted to improve food animals in terms of desirable characteristics such as growth rate and disease resistance. Furthermore, R&D is conducted to increase the value of animals in terms of improved meat yield, taste, texture, processing, and other characteristics.

Increasingly, R&D is working toward improved standardization of meat-producing species with desirable characteristics.

Background:

Livestock and poultry are highly important agricultural sectors in Ohio. In 2001, the Ohio livestock industry, for example, generated $1.9 billion in sales. But, its impact goes significantly beyond this because it is a critical link in a vertically integrated chain of production in Ohio. This chain begins with feed crop production and flows through to a large meat-processing sector (including 160 slaughter plants—ranking third in the nation). It has been estimated that fully 80 percent of Ohio agriculture is directly or indirectly related to the livestock and poultry industry in the state. Ohio ranks high in the nation in many aspects of poultry and livestock, including second in egg production, sixth in chicken production, ninth in hog production, 11th in turkey production and sheep/lamb production, and 10th in milk cow inventory.

OARDC/OSU R&D Strengths:

OARDC maintains well-rounded expertise in food animal improvement. Work is predominantly focused on

- Animal reproduction, breeding, and maturation
- Animal nutrition—optimized for growth, yield, and desirable characteristics (while nutrition cost and waste are minimized)
- Animal genomics and the identification of genes, and genetic markers, related to desirable and undesirable traits.

OARDC's research strengths in food animal improvement and genetics are greatly facilitated by the core scientific infrastructure in Wooster and Columbus. In Wooster, researchers have the benefit of a turkey research farm and dairy farm, together with beef cattle and sheep herds. Convenient to the Columbus campus, OARDC has a dairy facility; egg-laying facility; and herds of sheep, swine, beef cattle, and horses.

The facilities in Wooster are particularly important, with key resources including

- 350-head beef cattle confinement facility
- 200 cow/heifer dairy center
- 400-head sheep research center
- Poultry facilities including a 11,200-square-foot turkey facility, a 5,540-square-foot chicken pullet building, a 9,700-square-foot chicken meat bird building, and a 9,500-square-foot laying house.
- An animal genetics laboratory providing blood and deoxyribonucleic acid (DNA) typing, with an emphasis on cattle genotyping.

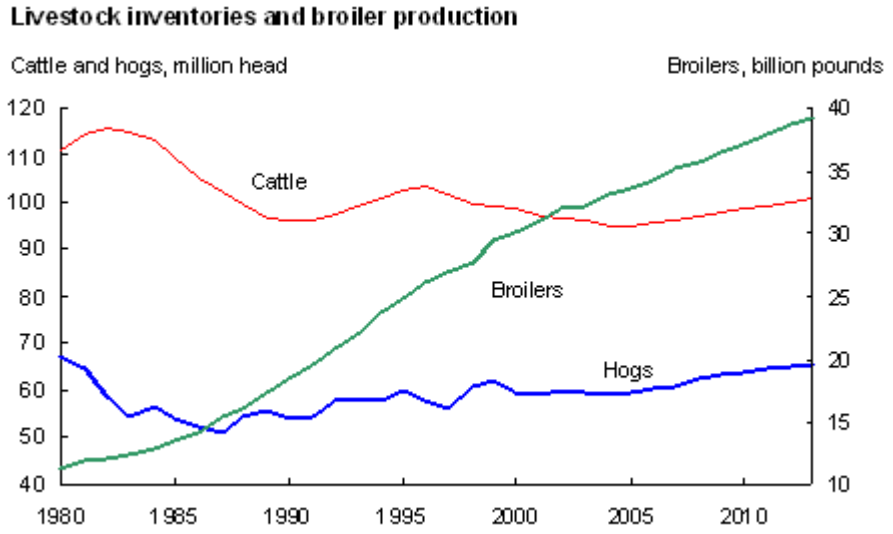
OARDC food animal genetics research has led to one recent start-up company, which currently is located on campus and is expected to locate to the BioHio Research Park when completed. This company has identified cross-population genetic markers statistically correlated with an animal's propensity to develop high value-added marbled beef. This discovery, together with associated research on beef tenderness, is

resulting in diagnostic tests that can be used early in the life of beef cattle to optimize expensive feed allocations based on genetic likelihood to produce the value-added marbled or tender beef.

Markets:

The markets for the type of food animal R&D being conducted at OARDC and OSU are large. The total estimated annual retail value of the U.S. beef industry is $70 billion, with a total population of 96.1 million head and an annual slaughter of 35.7 million head. Long-term trends point toward a decline in the consumption of beef (red meat) and a rise in the consumption of chicken and pork—trends that are favorable to Ohio given its higher ranking in chicken and pork production versus beef. Figure 13 illustrates U.S. market and production trends and projections.

Figure 13. US Livestock Market and Production Trends



Source: Economic Research Service USDA

U.S. egg operations produce circa 82.7 billion eggs, of which 8.2 million are produced in Ohio (ranking Ohio first, with Iowa second at 6.8 billion eggs). The total farm production value of U.S. eggs is 4.3 billion.

Given the highly competitive global market for livestock and poultry commodities, any OARDC R&D that leads to a marginal gain in the price realized for Ohio-produced meat, poultry, or eggs likely will have a large aggregate impact on Ohio producers. As an example of a value-added R&D contribution to beef production, OARDC developed a test for beef marbling whereby a producer, spending $10 for a diagnostic test, can realize an additional $100 from a marbled beef carcass.

In addition to basic commodity production and consumption markets, a growing market for transgenic animals is likely in the future. Multiple applications are projected for the use of transgenic versions of traditional livestock (such as pigs, cattle, and poultry) in areas as diverse as

- Marketable model animal systems and transgenic animal bioreactors
- Cloning and transgenic animal production systems

- Molecular farming, using livestock to produce medicines, nutraceuticals, and tissues for xenotransplantation purposes
- Transgenic animals with enhanced production and quality characteristics (such as increased meat or fiber yield).

Many diseases and disorders with a high level of unmet need can be treated successfully with the use of drugs created from transgenic animals. The world market for recombinant proteins was estimated at $12.8 billion in 1998, and the world market for antibodies exceeded $1 billion in 1998. Transgenic protein production offers significant economic and technological advantages over traditional methods of protein production—therefore, the market is highly likely to experience substantial growth. Advantages include reduction in the total amount of required capital expenditures, lower direct production cost per unit, and reduced risk of transmission of human viruses and other adventitious agents (Drug and Market Development). For some drugs, a herd of 600 transgenic animals could supply worldwide demand. OARDC's expertise in animal genetics and transgenics is likely to provide long-term opportunities for the University and Ohio in this potentially very large market.

Economic Development Potential:

Food animal agbioscience has the potential to provide economic development opportunities for Ohio along multiple pathways. Through the breeding of livestock and poultry with enhanced favorable characteristics, OARDC can drive increases in the economic value of Ohio's food animal output. An additional development path comes from R&D on trait markers and the development of diagnostics for early identification of positive traits in livestock and also the breeding of livestock carrying the positive genes. Animal cloning also is a potential area for Ohio food animal research, albeit a highly controversial one. Given that OSU also is home to a medical school with significant human biosciences research, there also is potential to link OARDC's expertise in animal genetics and transgenics to the production of model animal systems for biomedical research, animal "biorefineries," and organs/tissue for xenotransplantation.

Recommended Focus:

In the near term, applied food animal sciences at OARDC/OSU should focus on two principal areas: (1) marker and gene identification and the production and marketing of diagnostic tests, and (2) production of value-added animal breeds, via transgenics or traditional pathways, for the Ohio livestock and poultry system. Animal transgenics for biomedical purposes has a long-term development horizon, but discussions related to interest in this field should be opened up between the OSU College of Medicine and Public Health, the College of Pharmacy (for animal biopharming), and OARDC Animal Sciences.

TECHNOLOGY PLATFORM: ENTERIC AND RESPIRATORY FOOD ANIMAL DISEASES, INCLUDING ZOONOTIC DISEASES

Field Definition:

This field involves agbioscience R&D related to the prevention, detection/diagnosis, and treatment of infectious diseases of the food animal gastrointestinal and respiratory systems. R&D is conducted in areas ranging from the basic science and pathology of diseases and disease transmission, to the development of prevention strategies, diagnostic tests, vaccines, drugs, biologics, and treatment strategies.

Background:

Events of recent years, and even recent months, have served to highlight the devastating economic effects of food animal infectious diseases. The current avian flu outbreak in Asia is resulting in large-scale losses of poultry, and the disease is zoonotic (able to be transmitted from animals to humans and vice versa). At the writing this report, the disease had already spread to the United States with reports of avian flu among Delaware chickens. SARS similarly caused widespread economic distress in Asia and closer to home in Canada, while bovine spongiform encephalopathy (BSE, or Mad Cow Disease) has been detected in Canadian and Northwest U.S. cattle. The accidental, or deliberate, delivery of infected animals into the U.S. food production system has the potential to cause very significant economic losses in multiple areas of the production and processing chain, as well as threaten the biosecurity of the nation and its citizens.

OARDC/OSU R&D Strengths:

OARDC operates the formal Food Animal Health Research Program (FAHRP) that specifically focuses on economically important infectious diseases of food-producing animals. The FAHRP has a worldwide reputation among animal disease researchers and is especially well known for its work in

- Enteric food animal diseases
- Respiratory food animal diseases
- Immunosuppressive diseases in livestock and poultry.

OARDC's leadership in these areas of research is facilitated by some unique resources. Of special note is the germfree animal facility, which can house calves and swine—said by OARDC to be the only facility in the world for procurement and maintenance of germfree (gnotobiotic) food-producing animals. OARDC also is home to the world's only pathogen-free turkey flock. OARDC also is well equipped in terms of lab equipment and technologies for application in food animal health research.

The research program at OARDC demonstrates considerable breadth, with demonstrated expertise in microbiology, immunology, pathology, epidemiology, and environmental sciences and studies conducted at the animal, organ, cellular, and molecular levels. This breadth has resulted in multiple patented breakthroughs including diagnostic tests, reagents, and vaccines.

The international influence of OARDC in food animal health is further indicated by the fact that it now contains two worldwide reference labs for the development of standards in biologicals and vaccines.

Markets:

OARDC is well positioned for the development of an enhanced commercial position for Ohio in the food animal health market. By focusing on the two most common categories of livestock and poultry disease (enteric and respiratory diseases), the Center assures a large potential market for its discoveries and innovations. As noted earlier, the U.S. livestock industry generates more than $100 billion in revenues, and the USDA Agricultural Research Service estimates that the cost of diseases in livestock and poultry in developed nations equals 17 percent of total production costs. Disease prevention and treatment have long been high priorities among the U.S. farming community, but recent high-profile events are likely to lead to greatly increased demand for diagnostics, preventive tools, and treatments for food animal diseases.

Economic Development Potential:

OARDC Food Animal Health Research Program is one of the areas of OARDC R&D that has a track record in the production of biotechnology-based IP. Now that state legislation more actively encourages the formation of companies from faculty R&D discoveries, it is likely that OARDC will make active strides in the development of a food animal health and zoonotic diseases commercial sector for Ohio. Opportunities exist in the development of diagnostic tests, diagnostic reagents, vaccines, drugs, and biologics. Approaches to zoonotic diseases also open a potential pathway to the highly profitable human biomedical diagnostics, drugs, and biologics markets.

Recommended Focus:

A clear near-term focus of OARDC should be R&D leading to commercializable diagnostic tools, tests, vaccines, drugs, and biologics related to established and emerging food animal diseases. OARDC has been wise in focusing its research on major categories of disease, including enteric, respiratory, and immunosuppressive diseases and disorders; and this approach should be continued. Approaches to zoonotic diseases may benefit from liaison and multidisciplinary research projects between OARDC and human medicine researchers on the Columbus campus of OSU.

Technology Platform: Food Decontamination, Sterilization, and Associated Processing Technologies

Field Definition:

This field involves R&D and technology development related to the decontamination of food products and food processing and handling equipment via sanitizing, pasteurization, sterilization, and other means. Some of the latest technologies for sterilization and pasteurization also demonstrate promise as food-processing tools.

Background:

FDA data indicate that, in any given year, the seven most common food-borne pathogens cause between 3.3 million and 12.3 million illnesses. In approximately 4,000 of these cases, the infection will lead to death. The total monetary losses in the nation attributable to the seven most common food-borne pathogens have been estimated at between $6.5 billion and $13.3 billion annually. Based on Ohio's

population, these figures suggest between 132,000 and 492,000 food-borne illnesses in Ohio each year from the leading pathogens, with a cost of up to $530 million. In addition to the cost of human illness, the wastage of food waiting for testing is significant and leads to annual spoilage losses of between $5 billion and $6 billion nationwide. Technologies and processes that can speed the detection of pathogens and facilitate their eradication/deactivation on food products hold significant economic and societal value. Food processing is an $18.9 billion industry in Ohio. Furthermore, from the earlier economic analysis, it is known that food processing is the largest subsector in terms of employment, by far, but is in a state of decline. Between 1998 and 2003, the subsector lost 12 percent of its employment base, which represents a loss of approximately 7,250 jobs, leaving the food processing subsector employing 52,750 individuals across 1,142 establishments in 2003. Therefore, efficiencies gained through OARDC research have the potential to substantially impact this sector that has recently faced a declining trend.

OARDC/OSU R&D Strengths:

Scientists at OARDC and OSU are making important contributions to food safety along two primary technology pathways:

- OARDC scientists in Wooster have been working to improve the **speed and accuracy of contamination tests, to far more rapidly evaluate food for pathogens** in a timescale measured in minutes (when other technologies take up to 18 hours). This "rapid microbe detection" work, which employs real-time PCR technology, identifies signature DNA sequences from microbes that cause food-borne disease or spoilage. OARDC-developed technologies also reduce false positives by up to 99.9 percent—thereby virtually eliminating unnecessary food waste.
- At the Columbus campus, OARDC researchers have placed a major research emphasis on **developing new sterilization technologies to assure food safety and preservation**—technologies that not only assure food safety, but also preserve the taste, texture, and other favorable characteristics of the food product. OSU scientists and engineers have made significant advancements in the application of three new technologies: (1) ohmic heating using electric current to perform rapid and evenly distributed heat; (2) pulsed electric fields of between 25,000 and 40,000 volts per centimeter applied to a product passing through a tube via 2-microsecond pulses; and (3) high-pressure sterilization (at upward of 8,000 atmospheres)—a process that does not produce the food-damaging qualities of very high temperatures required in other techniques. OSU has constructed a pilot facility for the ohmic heating technology and is actively working with industry representatives in applied product testing.

The same OARDC research team looking at pulsed electric fields for sterilization also has found the technology to be suited to certain applications in **food processing**—including the processing of fruit. The short pulses of electrical energy blow holes in vegetative cells, causing the contents of the cells to leach out. This technology, a potentially effective tool in juice extraction and pasteurization, is being examined for applications in orange juice production. The ohmic technologies of OSU also are being applied in processing to greatly reduce (by an order of magnitude) the amount of lye required in the peeling process (with associated cost- and pollution-saving benefits).

Much of OSU's work related to safety and food processing and packaging is facilitated through the **Center for Advanced Processing and Packaging Studies (CAPPS)**. The mission of the NSF-funded CAPPS program is **"**to conduct industrially relevant research directed at developing methods and

technologies for the production of safe, marketable, high-quality shelf-stable aseptic and refrigerated extended shelf-life products." The main objectives of the CAPPS program are to

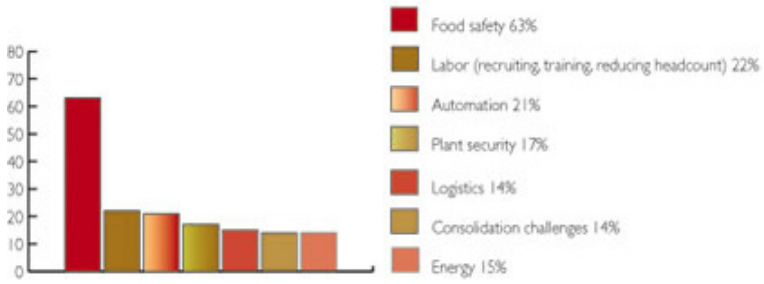
- Enhance safety and quality of aseptic and extended shelf-life products
- Characterize emerging, aseptic, and extended shelf-life processes
- Assure the integrity and functionality of aseptic and extended shelf-life packaging.

Currently, the OSU/OARDC program is unique in having three pilot facilities devoted to emerging technologies—including the first comprehensive, integrated pulsed electric field processing and aseptic packaging pilot plant, an ohmic pilot plant, and a high-pressure processor. Food Science and Technology is housed in a modern 40,000-square-foot facility with state-of-the-art laboratories and pilot plants that are connected to the Food Industries Center pilot plant and new biotechnology laboratories. One of the key differentiating characteristics of the CAPPS program is that it is set up and funded to be a collaborative and pragmatic institution working directly with industry. The program currently contains the membership of multiple industry organizations, including such industry leaders as the Coca-Cola Company, ConAgra, Gerber, Kraft, and Procter & Gamble.

Markets:

According to the National Food Processors Association, food processing is a $500 billion industry in the United States. Within the food processing industry, repeat surveys of manufacturers by the publishers of *Food Processing Magazine* have shown "food safety" to be, by far, the most critical issue to America's food products manufacturers. The results of their latest survey are shown in Figure 14.

Figure 14: Top Issues in the Operation of Food Processing Plants



Source: "Annual Manufacturing Trends Survey: Manufacturing Concerns for a Scary New World," Food Processing Magazine*, January 12, 2004.*

Economic Development Potential:

Tools and technologies for the rapid detection of microbes and contaminants and for reliable/cost-effective decontamination and sterilization of food products present distinct economic development opportunities for Ohio. Ohio is already home to the world market leader in hospital, medical device, and aseptic drug processing sterilization (STERIS Corporation); and working on advancing statewide expertise in food safety, sterilization, and associated processing technologies is a logical extension. Development potentials exist for the commercialization of products in a range of areas:

- Microbe/pathogen rapid detection systems and instrumentation
- Diagnostic tests
- New pasteurization and sterilization technologies using pulsed electric fields, ohmic heating, high pressure, or unique combinations of these and other decontamination technologies
- Advanced food processing and extraction technologies
- Advanced packaging and food-handling systems and technologies.

Recommended Focus:

It would appear that the current focus of the CAPPS program is on point and pragmatically led in partnership with industry—this is the type of model initiative that should be duplicated elsewhere within the OSU system. A focus on advanced sterilization and decontamination technologies and associated devices based on the work at the Columbus labs should remain a high priority for the University. In addition, the rapid microbe detection technologies being developed in Wooster have potential not only in food safety, but in biosecurity applications where monitoring for bio-contaminants will be a key growth sector.

Technology Platform: Ornamental Plant Genetics and Germplasm "Mining" for Functional Genes Useful in the Agbiosciences

Field Definition:

Ornamental plants are defined by the OPGC as aesthetically pleasing plants used in the home and urban landscape to enhance the quality of our lives. The category, therefore, is broad, encompassing plants as diverse as annual and perennial flowers to landscaping trees. Ornamental plant genetics and germplasm mining includes R&D work aimed at understanding the genomic profile of various plants and seeking useful genes and associated expressed chemicals for other agbioscience and medical bioscience applications.

Background:

As the "Biocentury" moves forward, genes with unique properties will become increasingly important and valuable. The world's biodiversity is huge, and the technologies of transgenics are facilitating the novel combination of species and genes to impart useful traits from one to another. A key component of the world's "genebank" is contained within plants (indeed, the maize genome contains more genes than the human genome). Ornamental plants (i.e., plants with aesthetic rather than food or fiber value) represent a substantial and extremely diverse component of the biosphere and thus may contain unique

and highly useful genetic qualities. The U.S. government has been establishing a series of genebanks in the United States, each of which is somewhat like a Ft. Knox for plants, where germplasm—seeds, bulbs, and other living tissue—is safeguarded. Without genebanks, genes that confer valuable traits such as natural resistance to insects or disease can be lost when plants that are popular today are replaced by newer, more popular or fashionable varieties. Genebanks are important to preserve current and older, heirloom varieties of plants, thereby maintaining the planet's genetic heritage and providing a rich resource for functional germplasm mining.

OARDC/OSU R&D Strengths:

OARDC and OSU have made important contributions, over many years, to ornamental plant breeding and development in Ohio. The Secrest Arboretum in Wooster is maintained as an outdoor research laboratory and display garden for plants suited to growing in Ohio and the Great Lakes region. Likewise, in Columbus, OSU's Chadwick Arboretum provides a multidisciplinary resource for research, education, plant preservation, and collections of plants within an aesthetic landscape. OARDC thus serves as an important R&D resource for Ohio's nursery sector, horticultural sector, and private and community landscapers and gardeners.

More directly relevant to agbioscience technology-based opportunities is the OPGC—designed to assist ornamental industries and consumers by

- Collecting, documenting, and conserving, long-term, genetic variation present in ornamentals and their wild relatives
- Exchanging germplasm domestically and internationally to broaden the genetic base
- Identifying and evaluating useful genetic traits desired by the industry and consumers
- Providing germplasm to industry for developing improved ornamentals
- Developing genetic maps of desirable traits for transfer into ornamental plants
- Identifying methods for successful long-term storage of ornamental germplasm as seed, tissue culture, and bulbs.

As with CAPPS, industry is an active supporter and partner with the OPGC—thereby providing good connections between university-based R&D and the nursery/ornamental sector. OSU was selected as the location for the Center after a competitive process and won because of its key resources, including

- Modern biocontainment facilities (to facilitate the study of non-native/exotic species and toxic species and for transgenics work).
- Large-scale greenhouse facilities
- Multiple field locations for growing ornamentals in multiple Ohio environments
- Arboretum resources for display introductions and field testing
- A base of existing ornamental research, with nine OSU faculty conducting ornamental plant production research and multiple graduate students in training
- Strong support and relationships with the ornamental plant industries.

Markets:

The USDA Agricultural Research Service calculates the sales volume of the U.S. floral and nursery crops industry at $12 billion annually. U.S. Bureau of Economic Analysis data show similar figures, noting that the "greenhouse and nursery product" sector had 2000 sales of $14.9 billion and employed 238,800 people nationwide. As in other industries, however, the floriculture and nursery products feed a vertically integrated industry and are important suppliers to the large landscape and horticulture sector (which in 2000 had economic output totaling $34 billion and employed almost 928,000 people). In Ohio these sectors also are important economic generators, with "greenhouse and nursery product" output of $612 million (with more than 9,000 employees) and "landscape and horticultural services" output of $1.3 billion (with 38,100 employees).

While the direct application of ornamentals to landscaping and aesthetic applications is a key industry, it also is important to note the potential biochemical, medicinal, and other applications for ornamental plant germplasm that may be found. The identification of active compounds of scientific and industrial value from ornamentals opens up the multibillion dollar pharmaceutical and nutraceutical industries as potentially linked markets.

Economic Development Potential:

At present the primary economic development role and mission of ornamentals within the OARDC/OSU system are to support the needs of the greenhouse/nursery/landscaping sectors in the state. However, long-term potentials exist to leverage the germplasm resources of the OPGC for gene and compound mining projects aimed at developing biopharming, pharmaceutical, and nutraceutical applications for ornamentals.

Recommended Focus:

The nursery and horticulture industry in Ohio has experienced fairly significant growth of approximately 8.5 percent per year since 1994. Applied R&D and extension services provided to this sector in Ohio are a legitimate OARDC economic development function. Gaining technology-based economic development from this strength area, however, will require a formal program being established to structure ornamental genomics research to link it to biotechnology, pharmacology, and other plant and medical bioscience initiatives that may result in novel and valuable resources from this resource of plant germplasm.

TECHNOLOGY PLATFORM: ENVIRONMENTAL PROTECTION AND DECONTAMINATION TECHNOLOGIES FOCUSED ON SOIL AND WATER

Field Definition:

This field nvolves R&D for the development of technologies for environmental monitoring, protection, pollution prevention, and decontamination and environmental cleanup.

Background:

The protection of Ohio's environment and natural resources is important for multiple reasons. It is imperative for maintaining and sustaining productive agriculture and agribusiness in the state. However,

cleanup of environmental pollution is extremely costly; while, increasingly, the quality of environment in a state is being seen as a key determinant in attracting and retaining high-skill, high-wage knowledge workers.

OARDC/OSU R&D Strengths:

Much of OARDC's research on the environment and its protection is conducted by affiliated researchers within the OSU School of Natural Resources. Some of the key areas of scientific leadership maintained with OSU/OARDC in this field include the following:

- The study of potential to sequester carbon in soils, thereby reducing damage to the ozone layer, is a key OARDC focus, with the Carbon Management and Sequestration Program examining no-till agricultural land practices and the benefits to carbon sequestration. OARDC research puts the potential value of sequestered carbon at $750 million to $2 billion for cropland. In addition, carbon sequestration has other benefits, including enhancing soil productivity, increasing yields, retaining nutrients and crop chemicals better, and reducing runoff of contaminants to the water system.
- Intensive programs of research are being conducted in terms of safeguarding water supplies from agricultural chemicals and other pollutants and in the use of artificial wetlands as mitigation tools.
- Microbiology and soil microbial community relationships to pollution mitigation is another focus of study. Here, applying microbes to contamination cleanup shows potential.

Markets:

Environmental Business International estimates that, overall, the U.S. environmental market stood at $182 billion in 1998 and was projected to grow at an annual rate of 1.8 percent through 2003. Within the environmental equipment sector, "water equipment and chemicals" comprise the largest subsector with an estimated $16 billion in sales, "waste management equipment" constitutes a $10 billion market, and "instruments, process and prevention technology" a $2.7 billion market.

In the mid- to long-term future, demand for general and industrial waste treatment and water and wastewater treatment is anticipated to grow as the social consensus to attain a richer life in harmony with the environment increases. Soil decontamination, PCB and dioxin treatment, and resource recycling are becoming pressing issues in society. In creating a recycling society, the environmental market is anticipated to expand, as will the need for flexible solutions.

One of the most important fields of application for modern biotechnology is environmental protection—whether in wastewater purification, ground decontamination, or the composting and fermentation of refuse. Biotechnological methods are based on the metabolic processes of micro-organisms and enzymes. They take place under relatively "soft" conditions, i.e., in water-based solutions, under normal pressure, and at low temperatures. If attempts to substitute "hard" chemical processes with "soft" biotechnological methods succeed, the environment is bound to benefit. It will no longer be polluted with toxic substances, such as organic solvents, heavy metals, and nonbiodegradable wastes. If biotechnological processes produce any residues at all, they are mainly highly biodegradable.

Economic Development Potential:

OARDC's work has the potential to generate potentially commercializable technologies in environmental monitoring systems and decontamination/mitigation technologies, especially those based on microbial digestion of pollutants and waste.

Recommended Focus:

Development of rapid diagnostic tests to check for pollutants/contaminants in water resources and Ohio's agricultural soils is recommended. Potential applications related to biosecurity and agrosecurity could assist in attracting and expanding funds. The development of microbes and microorganisms for pollution control and decontamination applications also is a logical economic pursuit.

Technology Platform: Composting and Advanced Potting Soil/Growing Media Development

Field Definition:

This field involves the development of growing media and soil improvement additives designed to enhance agricultural and horticultural productivity and plant health. It also includes the development of technologies to enhance compost, soil, and growing media production from waste streams and other potential biomass resources.

Background:

Composts, potting soils, and horticultural growing media may sound rather "low-tech," but their importance to a large world market for the growth of ornamental and food plants should not be under-estimated. While much agbioscience research focuses on the breeding and transgenic improvements to plants, far less of an emphasis has been placed on studying the impact of the soils in which plants take root and grow. As world population growth puts pressure on agricultural production, and as globalization pressures force U.S. agriculture to find new ways to enhance productivity, yield, and quality, R&D on all aspects of plants and their growing environment will be needed.

OARDC/OSU R&D Strengths:

Ohio is one of the leading states in the production of ornamental plants and in recent years, has established a growing nursery stock industry. The industry's growth largely has been sustained by groundbreaking OARDC research in composting and potting soils.

Statistics show that, prior to OARDC's development of bark-based mulch products, up to 75 percent of potted plants (such as rhododendrons and azaleas) died before they were sold, and most died post-planting. Through OARDC technologies that facilitate the nitriphying of bark, a new mulch industry was created that

- Generates disease-resistant potting soils that have reduced in-the-pot plant disease and losses by orders of magnitude. This has changed the economics of horticulture and promoted rapid growth in the nursery industry.

- Created a resource out of tree bark, which previously was a waste product to be burned. Multiple processing plants have been developed, both domestically and internationally, based on OARDC's mulching/composting technology.

It also should be noted that previous potting mixes required four to five fungicide treatments per season, at a cost of $9 per application per cubic yard of mix. OARDC potting mix is naturally disease resistant and requires only an occasional spot treatment, resulting in significant savings for producers.

Current research at OARDC is focusing on

- The chemical composition of soil organic matter and how it affects the abilities of specific microorganisms to induce plant disease resistance
- Projects yielding improved strategies for utilization of composts
- The development of new technologies for controlled inoculation of composts with biocontrol agents that induce systemic disease resistance in plants.

OARDC leadership in research related to soil science, composting, potting soils, and growing media creates fundamental opportunities for advances in the efficiency of America's and Ohio's plant production sectors.

Markets:

Premium soil, compost, and growing media products appear to be an expanding market. Data gathered by Vista Information Services, for example, shows potting soil sales at mass merchants, home centers, and hardware outlets grew 11.7 percent for the 12 months ended in October 2000. Dollar sales of premium potting mixes increased 42.1 percent, generating $165.5 million in sales.

Good quality compost also can be a source of profit and income for those who generate it. Wholesale prices (larger orders to professional end users) can range from $2 to $18 per cubic yard, depending on the quality of the product. Compost at a retail level typically will sell for $10 to $15 per cubic yard or higher, again depending on the quality of the product.

Overall, the outlook for the growing media market is considered to be very good (Vista Information Services).

Economic Development Potential:

Shipping and handling costs for soils and compost materials represent a significant component of their overall costs. As such, demand for premium Ohio-produced composts, potting soils, and growing media will be very much linked to the growth of the nursery and landscape industry in Ohio and adjacent states. As noted earlier, the nursery industry has experienced healthy growth in Ohio, but it is difficult to predict the rate at which growth will continue and its potential effect on economic development through soils and composting materials.

Current OARDC research related to soil microbial populations and their relationship to plant disease resistance may result in commercializable discoveries such as soil inoculants with probiotic or biocontrol characteristics that enhance plant health and disease resistance.

Recommended Focus:

Work should continue on increasing the quality of growing media while reducing its production costs. This may include R&D related to developing new technologies for producing and managing advanced growing media products and to potentially using various municipal waste, agricultural waste, and other waste streams in the industry. Continued OARDC work on probiotic and biocontrol inoculants shows considerable promise for potential "agbiotechnology" chemicals and products.

PRIORITIZATION OF NEAR-TERM OARDC DEVELOPMENT OPPORTUNITIES

The platforms and recommended focus areas identified present multiple potential development opportunities for Ohio. They do, however, vary in the potential size of their impacts, the scope of the economic sector in Ohio that may be built upon each platform, and the time required to realize such potential development. To assist OARDC in its economic development promotion decisions, a perspective on the prioritization of these opportunities is required.

Table 16 summarizes the key recommendations from the examination of each potential platform.

Table 16: Key Recommendations for Technology Platforms

Technology Platform	Recommendation/ Conclusion	Market Analysis
Genetics, transgenics, and breeding of food plants (focused on, but not limited to, soybeans and tomoatoes)	OARDC research should focus on the following: • Enhancing the functional food, phytochemical, and nutraceutical components of soybeans. • Establishing the health benefits of soybean phytochemicals and then increasing the expression of these beneficial chemicals in Ohio varieties. Represents opportunity to significantly increase the value of the Ohio crop and engender the development of the functional food and nutraceutical sectors in the state. • Extracting relevant nutrients and phytochemicals (or maintaining their active expression after food processing). • Continuing OARDC's ongoing work in disease and stress resistance and yield enhancement. • Pursuing tomato-based research along the same lines as that of soybeans. Could reap economic rewards for the state, but at a lower overall volume than realized by soybeans.	Large monetary opportunity given rapid growth of world-wide functional food and nutraceutical sectors. Critically important to increasing value and productivity of the key crop on Ohio farms—soybeans.

Table 16: Key Recommendations for Technology Platforms (continued)

Technology Platform	Recommendation/ Conclusion	Market Analysis
Genetics, trait marker identification, and associated breeding of food animals	In the near term, applied food animal sciences at OARDC/OSU should focus on two principal areas: • Marker and gene identification and the production and marketing of diagnostic tests • Production of value-added animal breeds, via transgenics or traditional pathways, for the Ohio livestock and poultry system. Animal transgenics for biomedical purposes has a long-term development horizon; but, discussions related to interest in the field should be opened up between the OSU College of Medicine and Public Health, the College of Pharmacy (for animal biopharming), and OARDC animal sciences.	Large monetary opportunity for advanced marker technologies and diagnostic tests for food animals. Opportunities to leverage OARDC genetics and transgenics skills for early entry into value-added animal production and transgenic animals. Opportunity to link transgenic animal expertise to OSU human medical research.
Enteric and respiratory food animal diseases, including zoonotic diseases	A clear near-term focus of OARDC should be R&D leading to the following: • Commercializable diagnostic tools, tests, vaccines, drugs, and biologics related to established and emerging food animal diseases. • Major categories of disease, including enteric, respiratory, and immunosuppressive diseases and disorders. OARDC has been wise in focusing its research on these areas and this approach should be continued. Approaches to zoonotic diseases may benefit from liaison and multidisciplinary research projects between OARDC and human medicine researchers on the Columbus campus.	Direct opportunity to continue OARDC IP generation and commercialization related to diagnostic tools, tests, vaccines, drugs, and biologics. Near-term opportunities to link clear OARDC skills in this area to large volume of funds being provided at the federal level for biosecurity and agrosecurity.
Food decontamination, sterilization, and associated processing technologies	• The current focus of the CAPPS program is on point and pragmatically led in partnership with industry—this is the type of model initiative that should be duplicated elsewhere within the OSU system. • A focus on advanced sterilization and decontamination technologies and associated devices based on the work at the Columbus labs should remain a high priority for the University. • In addition, the rapid microbe detection technologies being developed by OARDC faculty have potential not only in food safety, but in biosecurity applications where monitoring for bio-contaminants will be a key growth sector.	Significant opportunity for R&D discoveries leading to an expanded decontam-ination and sterilization equipment advanced manufacturing sector in Ohio. Opportunity to open biotechnology opportunities in microbe and contaminant detection (again with significant biosecurity funding possibilities).

Table 16. Key Recommendations for Technology Platforms (continued)

Technology Platform	Recommendation/ Conclusion	Market Analysis
Ornamental plant genetics and germplasm "mining" for functional genes useful in the agbiosciences	• Applied R&D and extension services to the rapidly growing nursery and horticulture sector in Ohio should be an OARDC economic development priority. • Gaining *technology-based* economic development from this strength area will require a formal program to structure ornamental genomics research that links to biotechnology, pharmacology, and other plant and medical bioscience initiatives that may result in novel and valuable compounds and resources from plant germplasm.	Enhancing Ohio's position in the lucrative ornamental plants/nursery business sector. Potential for very large economic returns on novel gene/compound discoveries useful to medicine within unique ornamental plant germplasm resources of OSU.
Environmental protection and decontamination technologies focused on soil and water	• Development of rapid diagnostic tests to check for pollutants/contaminants in water resources and Ohio's agricultural soils is recommended. • The development of microbes and microorganisms for pollution control and decontamination applications also is a logical economic pursuit.	Large worldwide market for environmental protection and remediation technologies. Near-term federal financing opportunities due to relationship to biosecurity and homeland security.
Composting and advanced potting soil/growing media development	• Work should continue on increasing the quality of growing media while reducing its production costs. This may include R&D related to developing new technologies for producing and managing advanced growing media products, and potentially using various municipal waste, agricultural waste, and other waste streams in the industry. • Continued OARDC work on probiotic and biocontrol inoculants shows considerable promise for potential "agbiotechnology" chemicals and products.	Potentially significant ag-chemicals market if biocontrol inoculants research at OARDC is successful. Long-term opportunities to reduce disposal and environmental costs of waste streams and gain value from them through advanced composting technologies.

Each platform presents opportunities for technology-based agbioscience economic development in Ohio. It is important to note that several of the platforms can be further enhanced by developing research partnerships between the OSU College of Medicine, College of Engineering, and College of Food, Agricultural, and Environmental Sciences. Interdisciplinary research has been a focus of OARDC for a number of years. For instance, OARDC staff has recently participated in a series of discussions regarding potential projects related to biomass processing with their peers within the College of Engineering. However, for Ohio to truly benefit from the wide array of research being undertaken within OSU, the institution's leadership must promote and provide support for more robust translational/interdisciplinary partnerships that transcend the traditional academic boundaries.

The following analysis estimates which platforms may provide the best near-term opportunities for significant agbioscience-led economic development in the state.

SUGGESTED PLATFORM PRIORITIZATION

High Impact, Near-Term Opportunity Areas: These platforms have substantial market opportunities and significant economic development potential for Ohio within the next 5 years.

Table 17: Technology Platforms with High-Impact, Near-Term Opportunities

Technology Platform	Near-Term Development Component
Genetics, transgenics, and breeding of food plants (focused on, but not limited to soybeans and tomatoes)	Expression of phytochemical, functional food, and nutraceutical characteristics in soybeans to add product value.
Genetics, trait marker identification, and associated breeding of food animals	Identification of useful/valuable trait markers and development of associated diagnostic tests, tools, and services.
Enteric and respiratory food animal diseases, including zoonotic diseases	Development of commercializable diagnostic tools, tests, vaccines, drugs, and biologics related to established and emerging food animal respiratory and enteric diseases. Development of commercializable diagnostic tools, tests, vaccines, drugs, and biologics related to zoonotic respiratory and enteric diseases. Relate work to biosecurity and agrosecurity to attract federal biosecurity funds (in addition to USDA, CDC, and NIH funding).
Food Decontamination, Sterilization and Associated Processing Technologies	Development of rapid microbe and contaminant detection technologies for deployment in food safety and biosecurity applications. Applied R&D to bring commercialization from advanced technologies in pulsed electrical fields, ohmic heating, and high-pressure sterilization.

High Impact, Long-Term Opportunity Areas: These platforms have substantial market opportunities but the time horizon for realizing successful economic development in Ohio will likely exceed five years.

Table 18: Technology Platforms with High-Impact, Long-Term Opportunities

Technology Platform	Long-Term Development Component
Genetics, transgenics, and breeding of food plants (focused on, but not limited to soybeans and tomatoes)	Development of soybeans optimized for bio-industrial chemical applications, such as biofuels, etc. Development of chemical extraction and preservation technologies for maintaining functional food characteristics.
Genetics, trait marker identification, and associated breeding of food animals	Development of transgenic animal varieties with enhanced characteristics of market value. Connection of animal transgenics to human biomedical research and production of organs/systems for xenotransplantation. Biopharming via animal production pathways.
Food decontamination, sterilization and associated processing technologies	Development of an enhanced sterilization and decontamination sector in Ohio, built on new OARDC technologies. Development of food processing applications for pulsed electric fields and other advanced technologies.

Table 18: Technology Platforms with High-Impact, Long-Term Opportunities (continued)

Technology Platform	Long-Term Development Component
Ornamental plant genetics and germplasm mining for functional genes useful in the agbiosciences	Discovery and development of biomedical and biotechnology applications for novel genes and compounds from ornamental plant germplasm resources.
Environmental protection and decontamination technologies focused on soil and water	Development of microbes and other technologies for the digestion and remediation of soil and water contaminants.
Composting and advanced potting soil/growing media development	Discovery and development of bio-inoculants for enhancing the biological health of plant-growing media.

Lower Impact, Near-Term Opportunity Areas: These platforms have market opportunities and economic development potential for Ohio within a five-year time horizon.

Table 19: Technology Platforms with Lower Impact, Near-Term Opportunities

Platform	Near-Term Development Component
Genetics, transgenics, and breeding of food plants (focused on, but not limited to soybeans and tomatoes)	General improvement of yield, quality, disease resistance, and associated "traditional" qualities of soybeans suited for the Ohio growing environment. Expression of phytochemical, functional food, and nutraceutical characteristics in tomatoes to add product value.
Environmental protection and decontamination technologies focused on soil and water	Accessing biosecurity funding to further develop OARDC/OSU R&D in soil and water monitoring and protection.
Ornamental plant genetics and germplasm mining for functional genes useful in the agbiosciences	Continued work to expand and enhance Ohio's nursery and landscape business sector.

Lower Impact, Long-Term Opportunity Areas: This platform has market opportunities, but the time horizon for realizing successful economic development in Ohio will likely exceed five years.

Table 20: Technology Platform with Lower Impact, Long-Term Opportunities

Platform	Long-Term Development Component
Composting and advanced potting soil/growing media development	Reduce disposal and environmental costs of waste streams, and gain value from them through advanced composting technologies and associated biomass conversion research.

To take full advantage of these agbioscience technology platforms, the State of Ohio, OSU/OARDC, and the Ohio private sector will need to address several gaps, as well as seize opportunities outlined in Table 21.

Table 21: Gap-Filling Needs and Opportunities for the Technology Platforms

Platform	Gap-Filling Needs and Opportunities

Genetics, transgenics, and breeding of food plants (focused on, but not limited to, soybeans and tomatoes)	• There is an opportunity to utilize soybean and tomato as model plants to develop a comprehensive systems approach that will integrate genetics, molecular biology, and biochemistry with the private sector to more fully realize potential benefits of converting genetic resources to commercial products. To develop this approach OARDC will need to:
	  • Expand its capabilities in bioinformatics, genomics, gene expression, metabolic profiling, traditional breeding, food science/biological engineering, technology transfer, and marketing.
	  • Establish a winter nursery, e.g. establish relationships with Southern Hemisphere collaborators.
	  • Purchase the necessary instrumentation to conduct high through-put genotyping and laboratory- and field-based phenotyping.
	  • Enhance the intellectual interaction of the North East Soy Center (NESC), an organization established by OSU that is comprised of regional land grant universities. This interaction can be enhanced through regional competitive grants programs to foster interaction among members of the NESC.

Genetics, trait marker identification, and associated breeding of food animals	• The use of animals and animal products for biomedical purposes has a long term development horizon, but discussions related to interest in the field should be continued between the OSU College of Veterinary Medicine, College of Medicine and School of Public Health, and the College of Human Ecology (potential for development of animal based nutraceuticals), the College of Pharmacy (potential for animal biopharming) and OARDC/OSU Animal Sciences. • Maintaining and enhancing OARDC/OSU Animal Sciences' leadership position in established areas of animal species genomics (turkey genetics, beef marbling trait markers, swine genetics, IGF and growth parameters in beef cattle) will require a continued foundation in basic quantitative genetics as well as an increased emphasis in molecular genetics. Establishing a leadership position in development of value added food animal products, including nutraceuticals, and enhancement of the leadership position in food safety will require a solid foundation in molecular and microbial biology, meat science, mammary biology and physiology, and nutrition. OARDC/OSU Animal Sciences should work, to the extent possible, to coordinate these activities across key groups such as those contained in the College of Veterinary Medicine, College of Medicine and School of Public Health, College of Human Ecology, and College of Pharmacy. Expertise contained within other departments of OARDC/OSU (such as the Department of Food Science and Technology) should be incorporated via collaborations. • OARDC/OSU should seek means to fund and build a Center for Metabolomics Research that would complement the established

Platform	Gap-Filling Needs and Opportunities
	emphases of genomics (gene regulation and manipulation) and proteomics (understanding and manipulation of the products of gene expression) that would facilitate collaborations by scientists with this expertise across college lines throughout the University. The focus would be to determine the most relevant and near-term applications of products of animal metabolism and how these might be altered or enhanced by nutritional interventions and microbial manipulations, as related to food animal products, and their influence on human health. • OARDC/OSU should also seek to leverage its expertise in animal genetics, meat science, mammary biology and nutrition with potential industry partners in the State of Ohio (Ross Products [Abbott Laboratories], Battelle, Procter & Gamble, Wendy's, and Iams) and academic partners (University of Cincinnati) to build and expand upon opportunities in the production and sale of value-added food animal products and nutraceuticals.
Enteric and respiratory food animal diseases, including zoonotic diseases	• The development of a Biological Safety Level 3 (BL3) is of critical importance in the continued development of this technology platform due to the need to be able to conduct research on highly contagious pathogens. Progress toward having the development of such a facility is underway ($30 million allocated to date). • OARDC has developed the Molecular and Cellular Imaging Center (MCIC), which is a valuable central resource whose importance has steadily grown. However, the cost of the equipment and maintenance is beyond the means of individual departments. In addition, the complexity of equipment is increasing which requires trained individuals to operate. $1 million + $200,000 annually would be required to keep the facility up to date. • The study of animal disease has significant synergies with the ongoing work within the College of Medicine. Discussions related to interest in the field should be explored. • With the increasing national emphasis on agrosecurity, and OARDC's related field of expertise, an Agrosecurity Program should be created to focus all OSU efforts in the field. It is envisioned that this entity will focus on the security of animal, plant, food, water, and environmental resources and collaborators would range from faculty in the School of the Natural Resources, the College of Veterinary Medicine, to the College of Medicine or others as appropriate. Outside units such as Battelle, a major player in the DHS effort, would also be included. This entity will elevate OSU in the arena and facilitate grant proposal development in the field.
Food decontamination, sterilization, and associated processing technologies	• There is a need to develop a food safety laboratory on the Columbus campus in order to ensure the continued development of this technology platform due to the needs of the rapidly developing advanced processing technologies unique to OARDC. A plan exists for the renovation of an existing facility. Professional architectural designs are complete with an estimated cost of $1.5 million. This renovation would help enable OARDC to remain competitive in food safety and food security.

Platform	Gap-Filling Needs and Opportunities
	• An opportunity exists to channel the energies of the more than 30 faculty members at OSU with declared interests in food safety and food security. A modest investment in a new program would give needed focus to the food safety programs within OARDC, across the university, at collaborating Ohio campuses (such as Miami) and at major collaborating institutions (such as North Carolina A&T State University). Annual funds are needed to establish a food safety program within OARDC. This is in line with the needs for the Agrosecurity Program described in the technology platform above.
Ornamental plant genetics and germplasm "mining" for functional genes useful in the agbiosciences	• Opportunities exist to produce secondary plant products to prevent disease and improve human health; bio-based materials that can be adapted for both private and commercial use to alleviate broad range of biotic and abiotic stresses; new specialized plant-based compounds for use as industrial additives and reagents; novel genes for transfer to economic crop plant systems; and germplasm that has high capacity to sequester carbon in non-biodegradable forms. • There is a however, a lack of genetic information about ornamental plants and how this information relates to end products and the ultimate commercial value of the ornamental plant traits. Therefore, there is a need to expand OARDC's expertise in bioinformatics, genomics, gene expression, metabolic profiling, traditional breeding, biological engineering, technology transfer, and marketing through intellectual collaboration across disciplines relative to research on ornamental germplasm. This will require better access to molecular biology instrumentation, the acquisition of rapid throughput genotyping, and laboratory- and field-based phenotyping.

Environmental protection and decontamination technologies focused on soil and water	• Create an interdepartmental program to address decontamination of terrestrial and aquatic sites contaminated by chemical and biological pollutants. This program would be faculty driven and include members from within and outside OARDC.
	• Develop a new interdisciplinary program to evaluate the spread of diseases that affect humans by wildlife vectors, including the role of soil and water systems in life-cycles of pathogens.
	• Strengthen OARDC ties with the NSF Environmental Molecular Science Institute currently involving faculty from the School of Natural Resources and the Colleges of Mathematics and Physical Sciences, and Engineering.
	• Expand continuing research to develop a fundamental framework for assessing and controlling bioavailability of pollutants in soil and water, which would:
	  ○ Develop methods for assessing bioavailability of pollutants to target and indicator organisms
	  ○ Develop relationships between concentrations of pollutants in the environment and physiological effects in target organisms

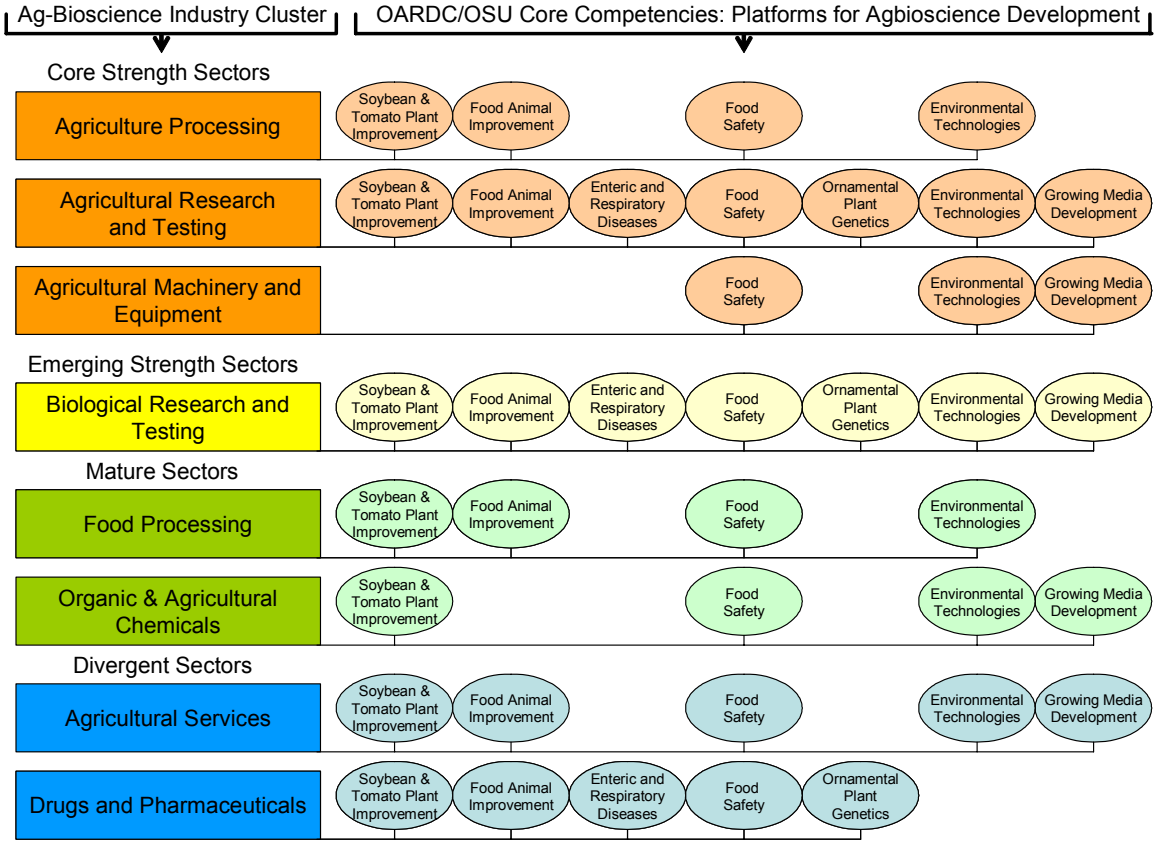
Platform	Gap-Filling Needs and Opportunities
	○ Develop protocols and commercially viable techniques for rapidly assessing pollution hazards in the field ○ Foster continuing research to develop chemical methods of decontamination, particularly in situ immobilization ○ Work cooperatively with USDA North Appalachian Experimental Watershed at Coshocton to expand utilization of facilities available at that location ○ Leverage current support to expand efforts in carbon sequestration as means of reducing CO_2 contamination of the atmosphere and improving soil quality, thereby reducing erosion. • To respond to an increased regulatory environment, instrumentation is needed to support research directed at rapid chemical and biological assessments of soil, water, and atmospheric contaminants. This capability needs to be expanded to include all terrestrial and fresh water aquatic systems. Funding for equipment would be approximately $1 million. • In addition to emphasizing techniques to characterize contaminants, OARDC requires molecular biological instrumentation to characterize functional groups of microorganisms in relation to the major chemical transformations they catalyze, including remediation of toxic substances and regulation of nutrient and carbon cycling processes. The end products will be management systems based on understanding and manipulation of specific metabolic pathways in soils and water so that nutrient cycles are more efficient and conservative and carbon storage can be enhanced.
Composting and advanced potting soil/growing media development	• To continue development of value added soil media, this technology platform requires a researcher (replacement for imminent retirement) trained in plant pathology related to potting media development, disease suppression, and other areas. Also needed is a technician (replacement for imminent retirement) to manage day to day field and laboratory data collection, data analysis, and set up of composting and greenhouse experiments. Funding for faculty and support personnel of $200,000/year. • There is also a need to upgrade laboratory facilities. Specifically, STAR LAB ($250,000) for energy measurement of compost and bioreactors and expanded capabilities to include infrared and nitrogen analyses. • Provide equipment for micro/molecular biology laboratory ($250,000) including centrifuges, DNA analysis equipment, and DNA micro-array equipment.

CONCLUSION

It is apparent through the study of these seven technology platforms that agbioscience is a clear target of opportunity for Ohio. Agriculture and agbioscience-related sectors in Ohio are important contributors to the Ohio economy. The dramatic changes being facilitated in the agbiosciences by genomic discoveries, transgenics, and other leading-edge advancements are bringing with them the potential to leverage Ohio's agbioscience strengths for technology-industry growth in the state. OARDC is well positioned to build upon its key strengths and leverage them for agbioscience economic development along a platform model.

Direct links exist between the quantitatively established current and emerging industry strengths in Ohio's agbioscience sector and the core strength R&D platforms observed and recommended for OARDC and OSU. These mutually beneficial links are illustrated in Figure 15.

Figure 15: Linkages between Agbioscience Industry and the Technology Platforms



The key focus moving forward must be to ensure that the proper infrastructure and investments are put in place to maximize the economic development potential for the industry. As the next section will show, expanding levels of vertical integration, maintained within the borders of Ohio, will yield expanding levels of economic development potential (in terms of business output and employment levels).

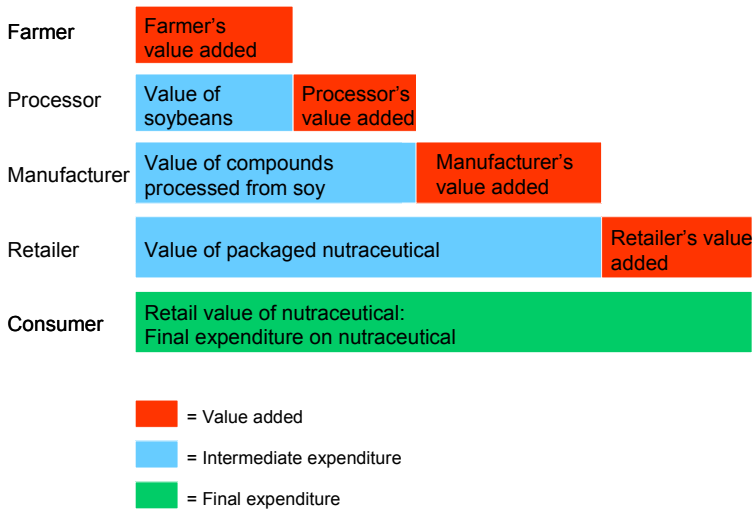
Realizing Additional Value from Ohio Agbioscience

Value-Added Chains of Production

Worldwide agricultural commodity markets are highly competitive and price driven. As a result, even though national agricultural productivity continues to increase, the real value of that production at "the farm gate" continues to decline. Current USDA statistics indicate that, on average, only 20 percent of consumer spending on food comes back to the farm. Commodity agriculture is a very low margin business and, in many crops, only economically viable through government farm subsidies.

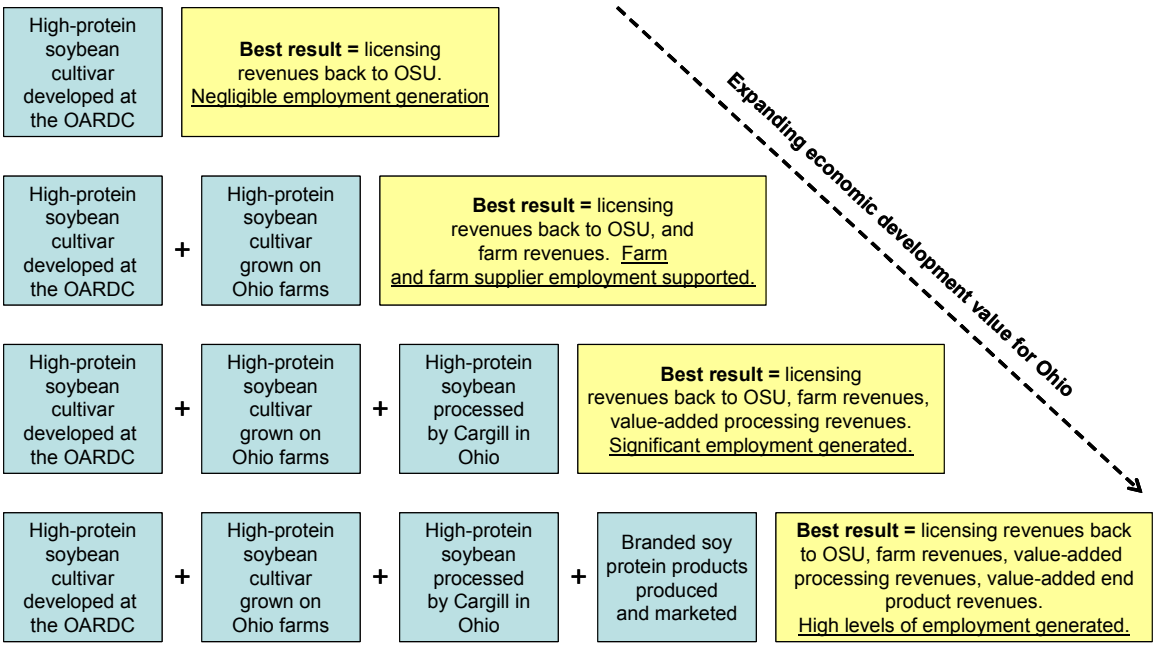
The future of agricultural and rural sustainability in a modern state such as Ohio will very much depend on the ability to construct "value-added" chains of production that vertically integrate agribusiness and agbioscience. The basic value-added concept is shown in Figure 16 and illustrates the substantial difference in potential income between simply growing and selling a soybean (the farmer row) and the total income that may be realized in a state that provides a vertically integrated value-added chain—in this example, by growing the soybean, performing the raw agricultural processing step, further processing the soy product to obtain chemicals and compounds of nutraceutical value, and then retailing them. An integrated value chain captures a far higher percent of the final dollar figure spent on the product for the state.

Figure 16: The Value-Added Concept—Soybeans to Nutraceuticals Illustrative Example



Alternative paths can be pursued to capture increased value added from agbioscience in Ohio. In models in some states, such as Iowa, farmers form processing cooperatives that then perform the processing steps subsequent to farm production. An alternative, but less integrated path, encourages the growth of individual companies serving each stage of the production and value-adding chain. In the highly agricultural Midwestern states, both of these paths typically are in place. However it is organized, an integrated value chain makes definite economic development sense. As Figure 17 illustrates, simply performing agbioscience R&D has a far lower potential economic return for Ohio than leveraging the discoveries from that science into an integrated production, processing, and manufacturing agbioscience sector.

Figure 17: Multiple Stages of Value Capture from OARDC-Developed High-Protein Soybeans

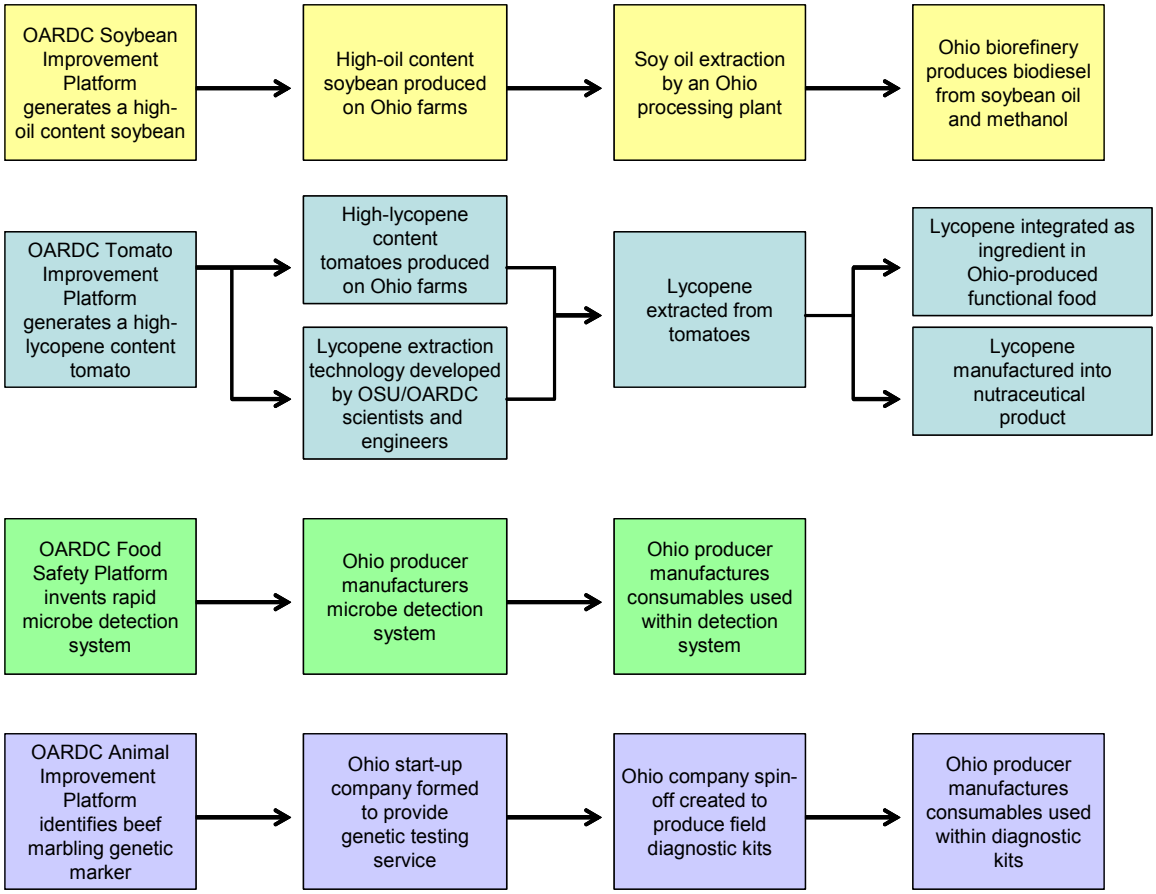


As Figure 17 illustrates, expanding levels of vertical integration, maintained within the borders of Ohio, yield expanding levels of economic development potential (in terms of business output and employment levels).

The technology platforms identified as priorities in this report lend themselves to economic development based on the formation of such value chains. The platform for food animal enteric and respiratory diseases, for example, could feed R&D discoveries into pilot- and production-scale sectors producing vaccines, diagnostic tests, drugs, and biologics. Likewise, the food safety platform could provide R&D discoveries related to pulsed electric fields that yield growth in Ohio's existing sterilization and decontamination equipment manufacturing sector. Further illustrative examples are provided in Figure 18.

Multiple examples of the agbioscience value chain are already at work in the United States and within Ohio. Indeed, the value capture model shown on Figure 17 is based on the actual development of high-protein soybean cultivars at the OARDC, their subsequent introduction on Ohio's farms, and the resulting attraction of a major industrial investment in the form of the Cargill high-protein soybean processing plant in Sydney, Ohio. Subsequently, the Cargill operation has expanded in multiple product directions. In 2000 Cargill Custom Dressings, a joint venture between Cargill and Hudson Company, was established in Sydney to produce mayonnaise, sauces, and salad dressings from soybeans processed at the existing Cargill plant. The Custom Dressings operation brought an investment of $25.8 million to Ohio.

Figure 18: Potential Integrated Value Chains for Ohio Based on OARDC Technology Platforms



Activities in other U.S. states illustrate the value-chain potential:

- In Iowa, the land grant university (Iowa State) has been at the forefront of developing high-productivity corn varieties suited to Iowa farm production. This led to Cargill opening a $120 million corn wet milling facility in Eddyville, Iowa, in 1985 to extract high-fructose corn syrup. Bob Parmalee, the General Manager of the Cargill plant, notes that since then they have been in a continuing state of construction as the Cargill plant moves into increasingly varied value-added products based on the corn feedstock. In 1990, a $50 million plant opened in Eddyville to produce citric acid (a widely used ingredient in foods, beverages, pharmaceuticals, and detergents). In 1993, this base was further expanded with the establishment of a $1.5 billion biotechnology process development research facility in Eddyville. Most recently, the "Biorefinery" complex and its related industries in Eddyville have expanded further with a joint plant constructed by Cargill and Hoffmann-La Roche to produce natural-source vitamin E. As Cargill continued to build and expand at Eddyville, two other companies built nearby plants that use Cargill's corn processing co-products as feedstock. Heartland Lysine produces lysine, a feed ingredient, and Ajinomoto USA produces monosodium glutamate. Other industry has grown around this bioprocessing cluster, and Eddyville now has two trucking companies with more than 800 trucks to handle the corn and corn-based products shipping requirements.

- A farmer-owned cooperative example of value-added chain development also comes from Iowa, where West Central Cooperative is now operating a $30 million soy manufacturing plant in Ralston. Using locally grown soybeans, the co-op annually processes 170,000 tons of SoyPlus, a highly absorbable protein used mostly by the dairy industry. In the late 1990s, West Central Soy, West Central Cooperative's soy processing division, expanded into methyl ester processing and biodiesel production. Iowa's first soy biodiesel production plant began producing biodiesel at West Central's Soy Center in Ralston in 1996. The cooperative also is producing soy-based biolubricant products based on research performed at the University of Northern Iowa.

Ohio's opportunities for building value-added clusters around core OARDC technology platforms would be facilitated by close, collaboratory relationships between industry sector representatives and the University. OSU already participates in one such collaboratory program—CAPPS, which is an NSF-funded Industry/University Cooperative Research Center. Three universities are participants in the CAPPS initiative, including OSU, North Carolina State University (the administrative lead), and The University of California at Davis. CAPPS is a center dedicated to the investigation of novel food processing and packaging technologies and to working with industry partners to commercialize these technologies. Through programs, such as CAPPS, that bring university scientists and industry comercialization experts together, the potential for creating synergies and business growth are significantly enhanced. Similar initiatives targeted at commercial leaders in other agbioscience and agribusiness sectors of relevance to the OARDC's strengths should be considered high priorities for the OARDC and OSU. By forming R&D collaborations with firms in sectors such as functional foods, nutraceuticals, veterinary medicines, vaccines, disease diagnostics, environmental technologies, etc., the University may be able to attract funding for additional high-profile centers.

CONCLUSION

Therefore, the future of agricultural and rural sustainability in a modern state such as Ohio will very much depend on the ability to construct "value-added" chains of production that vertically integrate agribusiness and agbioscience. Simply performing agbioscience R&D has a far lower potential economic return for Ohio than leveraging the discoveries from that science into an integrated production, processing, and manufacturing agbioscience sector. Instead, Ohio's opportunities for building value-added clusters around core OARDC technology platforms could be facilitated by close, collaboratory relationships between industry sector representatives and the University. A model by which this collaboratory relationship could be fostered is identified and described in the next section.

Potential Organization of OARDC to Position OARDC and OSU for Broad Leadership in Agbioscience Development

Potential Structure for OARDC

The preceding report sections provide detail regarding OARDC's core agbioscience competencies and how they may contribute to near- and long-term agbioscience economic development in Ohio, in particular by increasing levels of vertical integration, maintained within the borders of Ohio.

It is important to note, however, that in the "Biocentury," as the 21st century has been called, agbiosciences present a far broader opportunity for Ohio than only the identified OARDC/OSU niche core competencies. In this section of the report, the opportunity that exists to enhance and maximize the position of Ohio agbiosciences as a key driver of Ohio's Biocentury position is captured. To facilitate this, a potential structure for OARDC that would position the Center for maximum impact in agbioscience economic development is suggested—building on key strengths and taking advantage of potential market directions.

In the Phase I economic impact study, it was noted that OSU, because of past legislative restraints, has been limited in its commercialization of R&D discoveries and the creation of new business enterprises in Ohio. While OARDC accounts for more than 35 percent of current technology licensing at OSU, there is considerable room for improving the commercialization deal flow from the University and OARDC.

In recent years, the laws of Ohio were changed by the legislature to be far more favorable to entrepreneurship from Ohio's state universities. With these changes comes an impetus and desire for OSU to become a prominent player in the generation of new business opportunities for Ohio. OARDC, as the applied agbioscience R&D engine of the University, always has been focused on pragmatic solutions to real-world problems and the needs of agriculture and Ohio's farm communities. Now, this pragmatic mission has been expanded to actively encourage a broad range of economic development activities, including the following:

- The licensing of OARDC-developed technologies to Ohio business enterprises
- The spin-off of OARDC discoveries and technologies to create entirely new companies and employers for Ohio
- Collaborative R&D and commercialization projects between OARDC and Ohio commercial organizations.

Through these activities, it is expected that OARDC can enhance its position and importance as a core driver of Ohio's economic development. **Doing so, however, may require a formal structure—matched to the structure of the emerging Bioeconomy—to facilitate and encourage commercial agbioscience work and new business creation.** In this section of the report, a potential construct for such a structure is considered.

Agbioscience Development Pathways

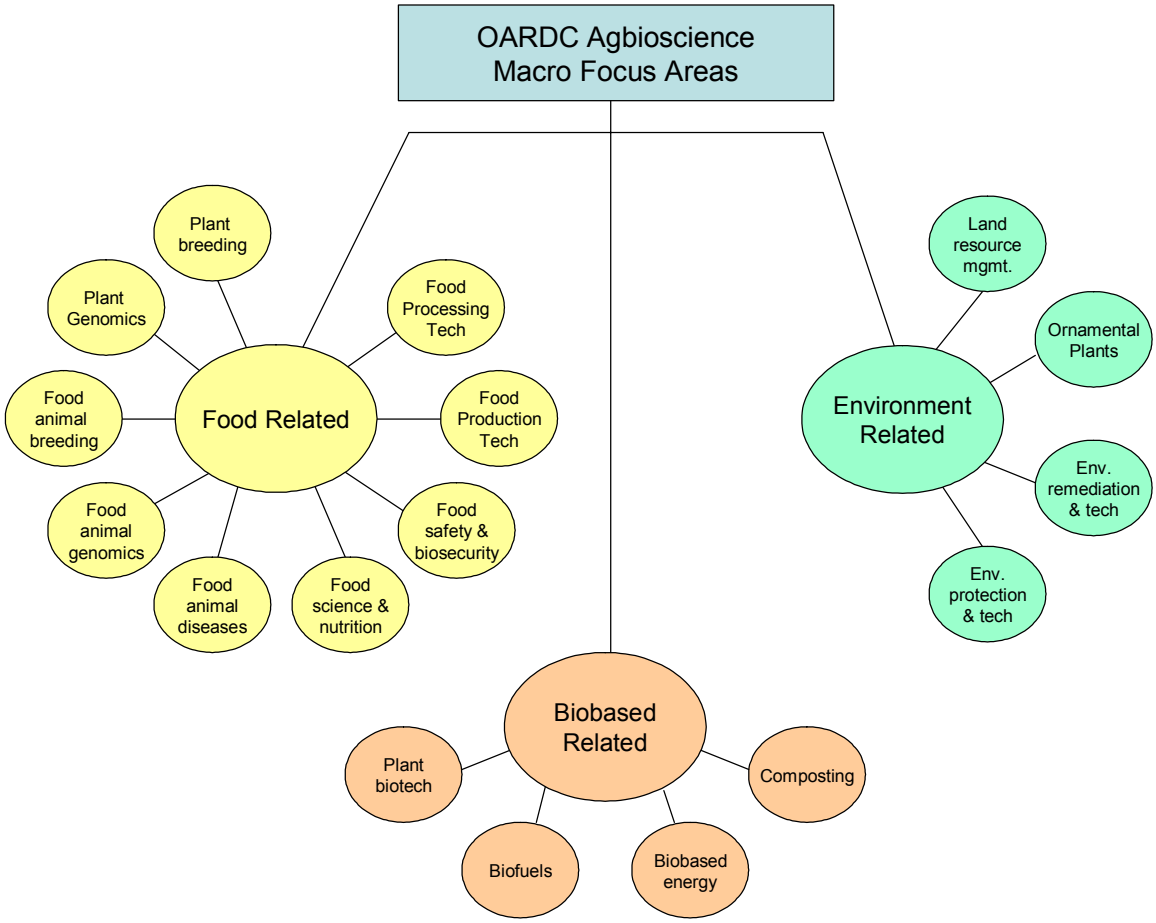
The review of OARDC strengths at a macro level indicates that ***three*** **primary development pathways are suited to the Center's expertise and future potential and are a good match to the main**

categories in which future agbioscience development may occur. These three pathways could drive the growth of the following three distinct macro-economic sectors in Ohio:

- **Advanced Food Economy Development—**Leveraging OARDC expertise in food science and technology, in combination with advanced R&D skills in plant and animal breeding, nutrition, processing technologies, and food safety.
- **Biobased Economy Development**—Creating progress in biotechnology and biorenewable industrial commodities to generate an enhanced agbioscience economy and new fast-growth business fields for Ohio.
- **Environmental Economy Development**—Using OARDC strengths in environmental sciences, resource management, and environmental remediation to generate new environmental business technologies and promote an enhanced environmental sustainability and quality of life for Ohio.

As Figure 19 illustrates, OARDC and OSU already have R&D initiatives that attach themselves quite naturally to these three broad themes.

Figure 19: OARDC/OSU Agbioscience Research Themes



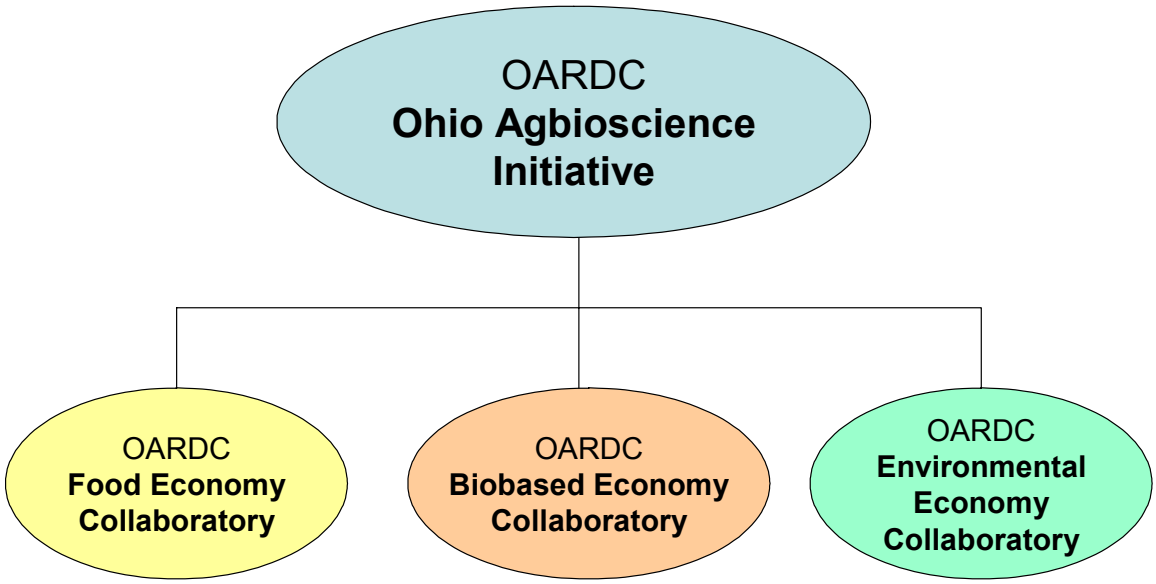
OHIO AGBIOSCIENCE INITIATIVE

Economy Collaboratories

These three macro opportunity areas would be best pursued under a formal structure designed to facilitate interdisciplinary work, innovation, and commercialization of agbioscience discoveries. The concept outlined below considers the potential structure of an "Ohio Agbioscience Initiative," under which three collaboratories would operate to drive R&D and foster agbioscience cluster development in Ohio.

The three potential collaboratories shown in Figure 20 are formed under an umbrella initiative termed "OARDC Ohio Agbioscience Initiative." The Initiative is designed to formalize and facilitate OARDC and OSU applied work to expand upon existing agbioscience sectors and *drive Ohio's leadership in newly emerging agbioscience and associated fields.* Furthermore, the Initiative is intended to counterbalance urbanization forces in the state by promoting new economic activity and sustainability for Ohio's agricultural producers and processors and the rural communities and small towns that depend upon them throughout Ohio.

Figure 20: Potential OARDC Collaboratories



Collaboratory Programs

As envisioned, each Collaboratory would be composed of programs that specifically draw upon OARDC's scientific, technical, and development core competencies to progress economic development initiatives in agbioscience. **These programs are envisioned as new *programmatic* entities for the facilitation of interdisciplinary research, development, and industrial collaboration—*not*** as a replacement for the existing departmental structures that exist under OSU College of Food, Agricultural, and Environmental Sciences. The three platform Collaboratories, and the programs that they contain, are discussed below.

The OARDC ***Food Economy Collaboratory*** would have the following five programs operating under its umbrella:

- **Food Plant Improvement Program**—Focused on the enhancement of the Ohio agricultural production and food processing sectors through the introduction of plant varieties, cultivars, crops, fruits, and vegetables with enhanced value and functional characteristics.
- **Food Animal Improvement Program**—Working to leverage OARDC's deep expertise in food animal breeding, genetics, nutrition, and health to create higher value livestock, poultry, and associated products.
- **Food Science and Nutrition Program**—Driving initiatives in innovative food products, nutrition, and dietary health through the incorporation of OARDC resources and those of OSU College of Medicine and Public Health.
- **Food Production and Processing Technologies Program**—Utilizing the skills of OSU engineering and OARDC food, agricultural, and bioengineering expertise to enhance and develop food production, harvesting, processing, and packaging technology commercialization for the state.
- **Food Safety and Agrosecurity Program**—Providing new economic opportunities and enhanced well-being through the development and application of new food safety, agrosecurity, and biosafety products and initiatives.

The OARDC ***Biobased Economy Collaboratory*** would serve as a formal rallying point for OARDC and OSU research in the application of biobased resources to the production of renewable resources, commodities, and biotechnology products. The Biobased Economy Collaboratory would have the primary role of finding commercial applications and business development opportunities for nonfood plant and animal biomass and farm waste products and processing by-products. Two programs are envisioned as operating within the Collaboratory:

- **Biorenewable Industrial Resources Program**—Working to research, develop, and introduce new products and technologies for creating valuable industrial commodities from biorenewable resources. Such commodities may include, for example, fuels, lubricants, fine chemicals, polymers, plastics, fibers, and composite building and construction materials from plant resources and biomass waste products.
- **Plant and Animal Biotechnology Program**—Using OARDC's skills in plant and animal genomics and related sciences to enhance the state's position in biotechnology. The program may engage in initiatives related to the production of vaccines, drug compounds via plant pathways (biopharming), biologics development, nutraceutical development, cosmetics development, xenotransplantation resources, and other applied R&D.

The OARDC ***Environmental Economy Collaboratory*** would leverage OARDC's expertise in environmental monitoring, protection, remediation, beautification, sustainability, and rural and urban quality of life to develop new products and agbioscience commercialization opportunities. The Collaboratory is envisioned as having two constituent programs:

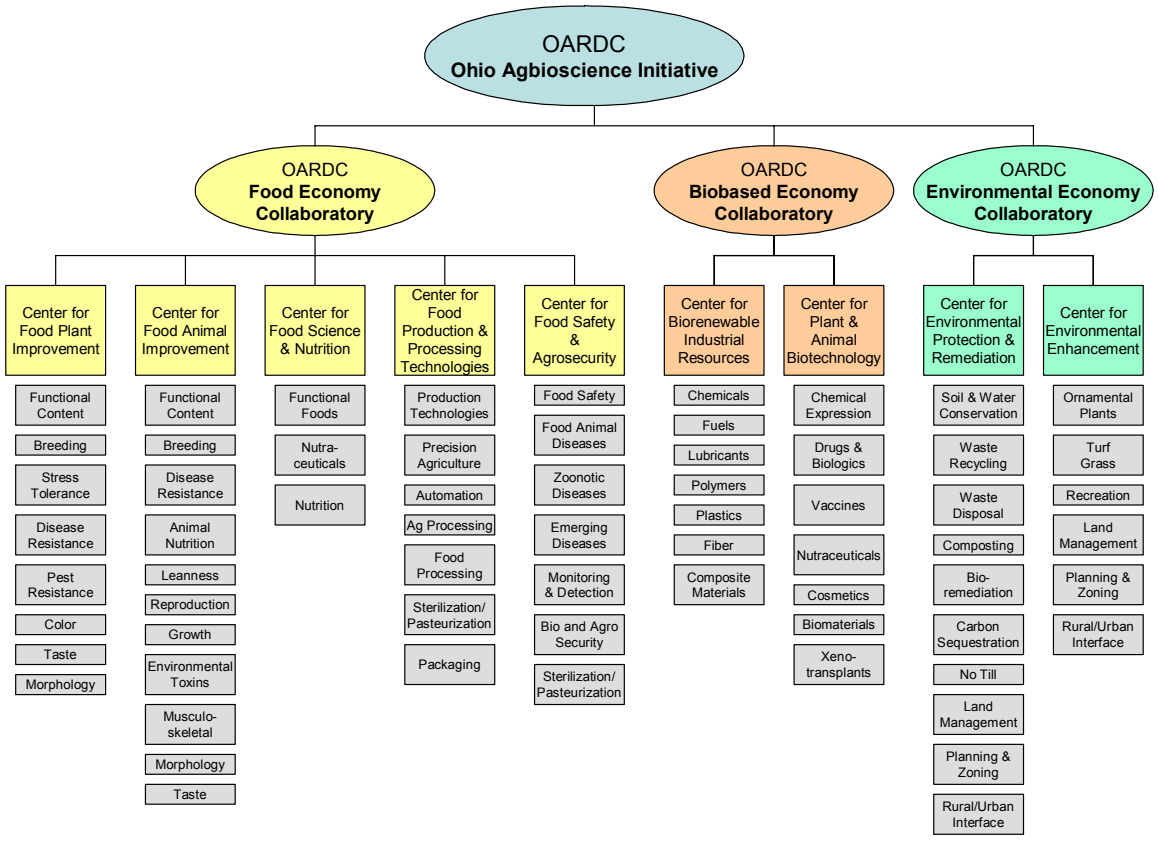
- **Environmental Protection and Remediation Program**—Working to develop new products and applications from OARDC expertise in composting, manure management, waste disposal, recycling, water preservation and treatment, soil conservation, phytoremediation, and carbon sequestration.

- **Environmental Enhancement Program**—Working to create commercial opportunities through ornamental plants, floriculture, and turf grass development and to enhance Ohio's urban and rural environments through landscaping applications.

Overall Structure and Budget

The overall structure of the proposed OARDC Ohio Agbioscience Initiative, with its three constituent Collaboratories and nine programs, is illustrated in Figure 21. The figure also identifies key components of OARDC R&D that would contribute to the success of each Collaboratory.

Figure 21: OARDC Ohio Agbioscience Initiative



As noted above, a formal suite of cross-disciplinary Collaboratories and programs under the umbrella of OARDC is a potential structure designed to encourage and facilitate agbioscience economic development in Ohio. It is envisioned that the Collaboratories would foster both ***internal*** interdisciplinary research among faculty as well as ***external*** linkages and interaction with industry. First, from an internal perspective, it is envisioned that the organization and development of each Collaboratory should run concurrently, with faculty and research scientists from multiple OSU/OARDC departments being asked to sign on as members of one or more Collaboratories.

From an external economic development perspective, while still recognizing the importance of building OARDC's interdisciplinary research base, it is critically important to find ways in which to foster linkages with industry and commercialize that research. Technology commercialization involves bridging

the gap between innovations and discoveries and the commercial development of those discoveries by agbioscience businesses. It is proposed that, in addition to its research mission, the Ohio Agbioscience Initiative and its three Collaboratories also will focus on providing commercialization assistance to agbioscience companies and technology entrepreneurs. The Collaboratories, by aligning themselves with the recent activities at OARDC such as ATECH and the BioHio Research Park, should leverage the experienced practitioners with expertise in technology transfer and commercialization. Furthermore, in staffing the various economic development initiatives underway, OARDC should give serious consideration to the core competency foci of the individual Collaboratories.

Overall, the external mission of the Collaboratories will be to transfer OARDC-developed technology and to assist companies seeking to commercialize new products and processes. The Collaboratories will serve to foster linkages with industry by

- Determining its research agendas based on industrial need, with industry driving the process
- Evaluating research coming out of the technology platforms to determine market opportunities through both technology and market assessments
- Evaluating commercial potential of patented technologies
- Forging partnerships with businesses interested in commercializing the agbiosciences
- Encouraging researchers to commercialize their research through licensing and spin-off opportunities and ongoing collaborations.

Each Collaboratory would be assigned a Director, with overall responsibility for forming an advisory board comprising University faculty and external industry representation. Since the goal of these Collaboratories is to drive practical application of agbioscience to enhance economic development of the State of Ohio economy, ideally, each individual Collaboratory should receive funds to

- Link companies with specific sources of expertise within the core competencies of the Collaboratories through industrial consortia membership relationships.
- Provide commercialization funding that would focus on developing research into commercial products or processes. Generally, funds are provided in the $25,000 to $100,000 range to undertake pre-prototype and applications review. This commercial function includes market studies and assessments, pre-prototype development, and even some limited follow-on research to determine commercial value of the IP.
- Work to increase understanding of OARDC's researchers of business needs and commercial applications.
- Maintain a close relationship with OARDC's researchers to ensure that the Collaboratories are fully informed regarding current research focus areas and discoveries.
- Develop and maintain Collaboratory/program promotional materials, communications pieces, newsletters, Web site, and annual report.

In the beginning, it is estimated that a budget of approximately $1.5 million to $2 million per year will be required for each Collaboratory. A significant portion of the funding will be used for commercialization projects, as described in the commercialization funding bullet above. Therefore, the anticipated initial $5 million annual investment ($2 million to the Advanced Food Economy Collaboratory and $1.5 million each to the Biobased Economy and Environmental Economy Collaboratories) should have significant

long-term impact on the agbioscience industry in the state by leveraging federal, industrial, and other sources of financial support to build a robust applied research program across the technology platforms. For instance, consideration should be given to requiring that a portion of the commercialization funds be matched by an outside source, so that the fund serves as a seed program designed to encourage faculty members to develop proposals for leveraging these dollars with additional funds from external grant and industry sponsor sources on pragmatic and applied R&D projects.

Summary

Tables 22 through 24 summarize the proposed Collaboratories. For each Collaboratory, the following information is included: the suggested mission, key potential participants, R&D programs to incorporate, primary OSU/OARDC departments likely to be participants, the potential R&D/product outputs, potential links to industry to facilitate cluster development, and key federal funding agencies.

Table 22: OARDC Food Economy Collaboratory

Mission	To develop and enhance the State of Ohio's position as a leader in the growing, harvesting, and processing of foods from Ohio resources and the production and distribution of value-added consumer and commercial food products and ingredients. The collaboratory will support multidisciplinary approaches to the • Development of advanced food plants and food animals • Advancement of human health via functional foods and highly nutritious food products • Invention and development of advanced technology and equipment for food production, processing, preservation, and packaging • Protection of human health through the development of protocols, practices, and technologies to assure the biosecurity of the agricultural production chain and the resulting food products.
Participants	Any faculty member or researcher at OSU and faculty and staff of other colleges and universities in the State of Ohio. R&D directors and senior research and managerial personnel at food processing and production companies.
Key R&D Programs	• Food Plant Improvement Program • Food Animal Improvement Program • Food Science and Nutrition Program • Food Production and Processing Technologies Program • Food Safety and Agrosecurity Program
Key OSU/OARDC Departments	• Food Science and Technology • Food Animal Health Research Program • Horticulture and Crop Science • Plant Pathology • Human Ecology • Food, Agricultural, and Biological Engineering • College of Medicine and Public Health • Ohio Plant Biotechnology Consortium

Table 22: OARDC Food Economy Collaboratory (continued)

Potential R&D/Product Output	• Enhancements to existing food crops in Ohio in terms of yield, disease resistance, morphology and processing characteristics, color, taste, and protein and nutrient content • Enhancements to food animals important to Ohio in terms of reproductive efficiency, growth rate, meat yield, meat quality, disease resistance, and other desirable characteristics • Functional foods and high-nutrient foods • Value-added applications and products from food crops and food animals • New technologies for food production, processing, preservation, packaging, and distribution • Monitoring devices, tests, diagnostics, and decontamination technologies to assure agrosecurity and safety of the food supply
Potential Industry Links	• Ohio farmers and agroproducers via OSU Extension • Agricultural machinery and equipment sector • Agricultural processing sector and manufacturers of processing technologies and machinery • Food processing sector and manufacturers of food processing technologies and machinery • Niche producers and marketers of emerging functional foods and high-nutrient food products • Manufacturers of biosecurity monitoring, testing, diagnostics, and decontamination equipment
Potential Government Links	• USDA • FDA • CDC • NIH • Department of Homeland Security

Table 23: OARDC Biobased Economy Collaboratory

Mission	To develop and enhance the State of Ohio's position as a leader in the production and processing of renewable biobased resources for applications in fuels, chemicals, and industrial commodities and for plant-based biotechnology. The Collaboratory will support multidisciplinary approaches to the development of • Existing, enhanced, and new plant crops for biobased economy purposes • Renewable biomass-based fuels, chemicals, polymers, plastics, adhesives, and lubricants • Biomass-based fiber and composite building materials • Production and processing operations to facilitate the application of biobased resources to industrial and commercial applications • Human and animal biotechnology applications of plant and animal resources.
Participants	Any faculty member or researcher at OSU and faculty and staff of other colleges and universities in the State of Ohio. R&D directors and senior research and managerial personnel at food processing and production companies.
Key R&D Programs	• Biorenewable Industrial Resources Program • Plant and Animal Biotechnology Program
Key OSU/OARDC Departments	• Horticulture and Crop Science • Plant Pathology • Food, Agricultural, and Biological Engineering • Ohio Plant Biotechnology Consortium
Potential R&D/Product Output	• Biofuels (e.g., ethanol, biodiesel, methane gas, etc.) • Specialty chemicals (e.g., plastics, adhesives, lubricants, catalysts, etc.) • Fibers (for carpeting, clothing, and other applications) • Biocomposite materials (e.g., construction materials, insulation, fiberboard, etc.) • Biotechnology products (e.g., drugs, biologics, xenotransplants, tissue, etc.)
Potential Industry Links	• Ohio farmers and agroproducers via OSU Extension • Agricultural machinery and equipment sector • Agricultural processing sector and manufacturers of processing technologies and machinery • Biorefinery operators and developers • Manufacturers of plastics, polymers, chemicals, fuels, etc. • Manufacturers of building materials and fiber-based products • Pharmaceutical and biotechnology companies
Potential Government Links	• Department of Energy • NSF • USDA

Table 24: OARDC Environmental Economy Collaboratory

Mission	To develop and enhance the State of Ohio's position as a leader in the application of biosciences to environmental protection, remediation, and enhancement. The Collaboratory will support multidisciplinary approaches to the development of • Technologies for reducing animal and plant waste products • Technologies for modifying or neutralizing agricultural wastes and agricultural chemical runoff to avoid harmful environmental effects • Advanced composting technologies and the conversion of waste products into useful resources (in collaboration with the Biobased Economy Collaboratory) • Pollution remediation, cleanup, and control technologies • Biological organisms for applications to waste/pollution digestion, conversion, and remediation • Ornamental plant resources for application to the landscaping needs of Ohio's urban and non-urban environments.
Participants	Any faculty member or researcher at OSU and faculty and staff of other colleges and universities in the State of Ohio. R&D directors and senior research and managerial personnel at environmental sector companies and companies facing environmental challenges.
Key R&D Programs	• Environmental Protection and Remediation Program • Environmental Enhancement Program
Key OSU/OARDC Departments	• School of Natural Resources • Food, Agricultural, and Biological Engineering • Horticulture and Crop Science • Food Animal Health Research Program • Plant Pathology • Ohio Plant Biotechnology Consortium
Potential R&D/Product Output	• Microbes for applications in the removal, degradation, and conversion of contaminants (such as organic chemicals or metals) • Biostimulation and bioaugmentation products to speed microbial decontamination processes • Custom-engineered plants for use in phytoremediation applications • Tracking and monitoring systems for environmental protection and biosecurity • Instrumentation, analysis, and measurement technologies and systems • Development of products from bio-waste streams and by-products (in partnership with the Biobased Economy Collaboratory)
Potential Industry Links	• Ohio farmers and agroproducers via OSU Extension • Pollution control and mitigation equipment manufacturing sector • Manufacturers of environmental monitoring, testing, diagnostics, and decontamination equipment • Manufacturers of biological and chemical products used in contamination cleanup and control
Potential Government Links	• USDA • Department of Energy • Environmental Protection Agency • Department of Homeland Security

OARDC Future Initiatives—Linking OARDC Plans to Core Competencies and Observed Opportunities[14]

As an R&D institution, OARDC has to maintain its position at the forefront of science in agriculture—this requires regularly adjusting and building upon its areas of research emphasis and expertise.

The 21st century has opened with dramatic advances in the biosciences. Advancements in genomics and post-genomic sciences have opened new avenues of study and paved the way for rapid progress in multiple areas of biology and the plant and life sciences. In response to the opportunities presented in what has been termed the "Biotech Century," the OARDC has multiple new and emerging initiatives aimed at leveraging life science advances and biotechnology for the benefit of Ohio and Ohioans. Upon review, it is evident that the majority of these new and emerging OARDC initiatives have direct or indirect linkages to our recommended core competency platforms.

Chief among the new and emerging scientific initiatives of the OARDC are

- The Ohio Plant Biotechnology Consortium
- Ornamental Plant Germplasm Center
- Emerging infectious diseases research program and the Plant and Animal Agrosecurity Research facility
- Bio-based energy program.

In addition to the above OARDC initiatives, the Center is also engaged in multiple projects specifically geared to economic development and the leveraging of new scientific discoveries into commercial opportunities in the state. At the forefront of the OARDC's work in this area are the ATECH Initiative (formally entitled the Food and Agricultural Technology Commercialization and Economic Development Program, funded in part by FY 2004–2005 Ohio State Budget) and the BioHio research park and business incubator.

The OARDC also is funding several new interdisciplinary programs, including

- The Agroecosystems Management Program
- The Ohio Composting and Manure Management Program
- Organic Food and Farming Education and Research Program
- The Urban Landscape Ecology Program.

In addition, the Center is taking the leadership role in multiple externally funded R&D initiatives, including

- The Ohio Aquaculture program, which is federally funded
- The Center for Advanced Processing and Packaging Studies, funded by the NSF
- The Center for Innovative Food Technology, funded by the USDA.

[14] This section of the report is adapted from our previous report for the OARDC entitled, "OARDC: A Generator of Positive Impacts for Ohio" (December 2003).

OARDC Initiatives—Links and Contributions to the Identified Core Competency Platforms

Ohio Plant Biotechnology Consortium

Headquartered at, and administered by, the OARDC in Wooster, the Ohio Plant Biotechnology Consortium has been established to facilitate collaborative work in Ohio biotechnology between 11 Ohio-based institutions.[15] The primary mission of the consortium is the pooling of scientific resources and talent to accelerate Ohio's plant biotechnology research and efficiently develop new plant and plant-based technologies. Benefits to Ohio are anticipated to come via

- The attraction of increased levels of external research funding into Ohio, especially given the preference of federal agencies such as the NIH and NSF to fund multi-institutional collaborative research
- The advancement of life sciences and plant biotechnology research in the state
- Improved commercial development of technologies and the applied development of new bio and bio-based products for Ohio's agriculture, food processing, biomedical, and other related sectors
- The leveraging of talent and resources from across the state, creating a whole that is greater than the sum of its parts.

Initial projects of the consortium have focused on developing mechanisms in soybeans to control insects and disease without applying chemicals, developing cold-hardy palms, and establishing genomic libraries for crop plants. Areas of continued exploration and research focus for the consortium are most likely to include recombinant DNA technology, pest resistance, bioremediation via plants, plant nutrition, new uses for traditional crops, nutraceuticals, and novel plant products.

***Core Competency Linkages**—The Ohio Plant Biotechnology Consortium has an obvious link into the Genetics, Transgenics, and Breeding of Food Plants Technology Platform. However, it also may contribute to several other platform and broad focus areas, including the Ornamental Plant Genetics and Germplasm Mining Technology Platform and the Food Economy and Biobased Economy Collaboratories.*

Ornamental Plant Germplasm Center

The OPGC has been established at the Columbus campus as a joint project between OSU and the USDA. The primary mission of the center is to "conserve and nurture the world wealth of herbaceous ornamental plant diversity."[16] The center is one of 24 germplasm repositories in the National Plant Germplasm System. OSU established the OPGC with the goal "to build the OPGC into the world's leading herbaceous ornamental plant genebank."[17] As an extension of this goal, the center will work not only on genebanking, but also on research and development, education, and training.

[15] Membership of the consortium includes OSU (with consortium administration operated by the OARDC), Bowling Green State University, Cleveland State University, Kent State University, Medical College of Ohio, Miami University, Ohio University, University of Cincinnati, University of Toledo, Wright State University, and Youngstown State University.
[16] http://opgc.osu.edu/main.asp?ID=2.
[17] http://opgc.osu.edu/main.asp?ID=2.

As noted earlier in this report, the possession and presence of a germplasm repository presents Ohio with an important resource for future research and development initiatives. Through biotechnology techniques, the genes and genetic traits of one species can now cross species boundaries to impart beneficial characteristics in completely unrelated species. For example, a cold hardiness gene may be found in a particular ornamental herbaceous plant that may subsequently be transferred into other plants such as soybeans, tomatoes, or wheat. The possession of germplasm thus forms a basic building block upon which scientific progress and discoveries may be made.

The OPGC has been established not only to conserve and preserve germplasm, but also to serve as a part of a system designed to promote industry-oriented collaboration and enhance the commercial application of germplasm resources and knowledge. To this end, one of the goals of the OPGC is to build a network of partners and collaborators from academe, the horticultural industry, biotechnology industry, botanical gardens and arboreta, and the USDA.

Through the preservation of germplasm and the controlled dissemination of valuable germplasm for research and development purposes, the OPGC may be a resource to assist academic and industrial scientists develop future crops that are resistant to pests and disease; more efficient in their use of nutrients and environmental resources; and more appealing to the marketplace because of improved color, texture, taste, smell, or nutrition characteristics. The germplasm may also be valuable in applications outside of agriculture and horticulture—presenting opportunities in the discovery of medicines, chemical products, and other commercializable resources.

In working to achieve these goals and potentials, the OPGC will initially concentrate on the following activities:

- Collecting, documenting, and conserving genetic variation present in ornamentals and related plants in the wild
- Exchanging germplasm domestically and internationally to broaden the genetic base
- Identifying and evaluating useful genetic traits desired by the industry and consumers
- Providing germplasm to researchers in industry, universities, and other institutions for developing improved ornamentals
- Developing genetic maps of desirable traits for transfer into ornamental plants
- Identifying methods for successful long-term storage of ornamental germplasm as seed, tissue culture, and bulbs.

As noted previously in this report, after a period of dramatic growth in the 1970s, 1980s, and 1990s, the nursery and horticultural industries today represent the largest component of Ohio's agricultural production sector. OARDC research conducted in 2001 indicates that overall sales by certified nursery stock dealers and producers in Ohio totaled $2.79 billion with more than 96,000 persons working in the industry. Having a resource such as the OPGC dedicated to preserving and enhancing the ornamental plant germplasm resources in the state may result in new plant varieties, strains, and characteristics that will impart a competitive advantage for the sector in Ohio.

Core Competency Linkages—Direct *via the Ornamental Plant Genetics and Germplasm Mining Technology Platform.*

Emerging Infectious Diseases Research Program and the Plant and Animal Agrosecurity Research Facility

The widespread movement of people, goods, and commodities via rapid intercontinental transit and the increased globalization of trade have brought tremendous economic advantages to the United States' free trade, capitalist economy. While globalization has brought with it sustained economic advantages for the nation, it also comes with risks—risks imposed by the potential movement of diseases into the United States via accidental or deliberate (i.e., terrorist) means.

Today's U.S. agriculture is highly efficient, productive, and healthful based in large measure on the concerted science work of agricultural R&D centers such as the OARDC and the application of new technologies, techniques, varieties, and know-how by America's farmers and livestock producers. The stability and economic viability of this finely honed system of livestock production depend, however, on the maintenance of healthy animals. Indeed, the economic health of crop farmers in Ohio also depends on livestock health and demands because fully 80% of Ohio's crops are sold as livestock feed in a value-added process of producing high-quality, high-value meat and poultry. Emerging infectious diseases therefore represent a tremendous potential threat to agriculture in Ohio and the United States as a whole.

Infectious disease outbreaks in livestock can have a devastating effect on an economy rooted in agriculture. The foot and mouth disease outbreak alone in the United Kingdom resulted in estimated economic losses totaling $15 billion. Very large levels of economic disruption could be caused in the United States by the spread of such a disease either by accidental transmission or by a deliberate bio-attack by terrorists or other enemies of the United States.

As discussed under the core competency analysis, OARDC maintains deep levels of expertise in infectious animal diseases and is home to the Food Animal Health Research Program—a program that contains some of the worlds leading experts in highly contagious respiratory, enteric, and other animal diseases. When the coronavirus SARS emerged as a pathogen with worldwide threat status, OARDC animal virologists were brought in by the CDC, NIH, and the U.S. Department of Defense to consult on the threat and approaches to be taken. The establishment of a formal animal agrosecurity initiative at OSU and the OARDC is a natural extension of the existing base of expertise and offers economic development potential for the state in developing

- Rapid detection diagnostics tools, systems, and processes—tools likely to be in high demand both domestically and internationally
- Vaccines and other preventive tools
- Drugs, biologics, and treatment regimens to suppress outbreaks
- Quarantine, culling, and other systems and protocols to contain outbreaks and reduce the threat of diffusion.

The work in animal agrosecurity is likely to be significantly enhanced at the OARDC by the recently funded BL-3 facility—providing a resource for the containment and study of highly infectious disease organisms and pathogens. Designed as a one-of-a-kind facility, the planned OARDC BL-3 installation will combine resources for isolating and studying both plant and animal organisms (thereby making

optimal use of scientific and infrastructural resources). The OARDC anticipates that the BL-3 installation will facilitate three primary research areas:

- Emerging Animal Infectious Diseases—especially the investigation of zoonotic diseases (diseases that can transfer from animals into the human population).
- Insect/Vector-Borne Diseases—with the initial thrust being on vector-borne diseases of plants. The OARDC expects that one area of focus will be biocontrol, whereby insects (including exotic insects) may be used as predators to control pests (such as soybean aphids).
- Plant Diseases—with a focus on diseases that have not yet entered the Ohio environment but pose a risk of doing so. By working on these diseases (e.g., soybean rust) in a controlled environment, the OARDC can perform research to assure that the state is ready to deal with plant infectious disease outbreaks that may occur in the future. It is also expected that the BL-3 facility will be used for the safe conduct of transgenic experiments.

Core Competency Linkages—*The above cited initiatives are* ***directly connected*** *to the more narrowly focused Enteric and Respiratory Food Animal Diseases Technology Platform. This focus also is supportive of the broader Food Economy and Biobased Economy Collaboratories.*

Bio-Based Energy Program

Bio-based energy initiatives hold promise for creating benefits for farmers, industry, consumers, and the environment. Bioenergy comes from natural sources such as agricultural, forest, and aquatic resources, and has the potential to produce a wide variety of commercial products including fuels, electricity, chemicals, adhesives, lubricants, and building materials.

Fuels from biomass have taken root in the United States. Ethanol produced from corn is one of the most visible of the existing products, but other applications of bioproducts are also in the marketplace. The U.S. Department of Energy and other policy makers have placed a priority on developing alternatives to fossil-based fuels and chemical products because these nonrenewable sources are being depleted and because biofuels would help the U.S. economy become less dependent on foreign fossil-fuel sources. With an emerging bio-based industry, agricultural research and development is moving beyond the traditional areas of food, feed, and fiber and is showing promise for a bio-based economy that will

- Be rooted in life sciences coupled with bioengineering processes
- Reduce the U.S. vulnerability in terms of access to and supply of petroleum for energy and industrial products
- Increase the sustainability of U.S. industry via the use of a domestically produced and indefinitely renewable base of plant resources
- Use R&D to become increasingly cost effective against depleting fossil-fuel resources
- Create new commodity outlets for farmers, increasing the economic viability of the farm and helping to create both rural and urban employment opportunities in new bio-based industries
- Produce value-added bio-based products (fuels, chemicals, and materials) for domestic use and for earning export dollars
- Provide demand for plant-based biomass that may be grown throughout the United States, rather than reliance on fossil-based resources that are present only in limited localities

- Improve the environment through lowered emission levels of pollutants, reduced acid rain, and reduced greenhouse gases.

Potential exists within the OARDC/OSU research establishment for the institution to adopt a position in certain aspects of bioenergy and biofuels. One of the OARDC's current programs is focused on energy production from waste streams, and the team has taken the unique approach of examining the potential in higher-order waste streams generated within the food processing industry—an important industry in Ohio. By leveraging expertise in anaerobic digestion, microbiology, biochemistry, and engineering, it is anticipated that OSU may produce new processing technologies that provide two central economic benefits: (1) generating gases for the production of energy commodities and (2) substantially reducing waste streams that currently have significant disposal costs associated with them. OSU researchers are also working on biodiesel fuel, with the initiative focused on producing fuels from soybeans. Industry in Ohio is starting to take note of the progress being made on bioenergy and biofuels at the OARDC and OSU, and the potential exists to expand the research initiatives significantly into a formal research center. Further funding for infrastructure, such as a pilot plant digester, is required to move the research and application of research findings to the next level on the path to commercialization.

Core Competency Linkages—*The Genetics, Transgenetics, and Breeding of Food Plants Technology Platform includes work related to bioenergy transgenics for oil and other biofuel chemicals from soybeans. The vision for a broader collaboratory focus at the OARDC calls for a specific emphasis on the biobased economy and biorenewable industry applications of Ohio crops and biomass.*

ATECH Program

This initiative, titled the Food and Agricultural Technology Commercialization and Economic Development Program (ATECH), aims to foster and accelerate development as a result of university research and extension programs with a primary focus on food, agricultural, environmental, and life science technologies.

ATECH is designed to maximize the commercialization potential of OARDC research, and will be formally staffed with personnel dedicated to realizing this potential. The staff will work to assist faculty staff and students in identifying and protecting IP—it will then facilitate the commercialization or technology transfer of the technologies or knowledge into the private sector via new business enterprise formation or the licensing of technology to new or existing commercial entities. It is also anticipated that ATECH will provide technical evaluation and market analysis services to both newly establishing and established companies.

At the current time, food, agricultural, and environmental sciences at OSU are a leading generator of IP, royalties, and licensing revenues for the university. The ATECH program is being developed to build on this existing track record through a formalized, professionally staffed service. With initial funding of more than $580,000, the ATECH program will recruit two senior staff into "Development and Marketing" and "Technology Commercialization" leadership positions, supported by two associates providing administrative and IP support. These positions are designed to dovetail with the BioHio Research Park development, helping to provide an integrated turnkey service for promoting ag-related economic development including applied research; commercializable IP protection; commercialization planning and development; industry partnerships; and co-location of new, established, and emerging agbioscience businesses on an OARDC research park.

Now that state legislation has been changed to favor and encourage faculty entrepreneurship, it is anticipated that more business development opportunities will emanate for OARDC research. This

already is proving to be the case with new commercial endeavors being ready to spin out of OARDC, including technologies in

- Commercial beef cattle diagnostic tests using genetic markers for beef quality characteristics such as meat marbling and tenderness
- Software and computer visualization systems for the rapid analysis and prediction of seed vigor
- New technologies for food preservation and decontamination based on ohmic heating, pulsed electrical fields, and high-pressure sterilization.

***Core Competency Linkages**—The ATECH program will be a fundamental component of the success of all three Economy Collaboratories since the initiative aims to maximize commercialization and economic development through linkages with industry and the commercial marketplace. It is recommended that prioritization be given to the technology platforms that have been prioritized as having the greatest near-term economic development potential.*

BioHio Research Park

While the OARDC has been a generator of applied scientific research for the benefit of Ohio agriculture, legislative restrictions (which changed in 2000) on faculty engagement in commercial spin-offs limited its forming of new business enterprises. In addition, a lack of commercially oriented facilities, labs, and offices adjacent to the OARDC research complex placed limitations on creating local economic development benefits from OARDC/industry collaborations.

To foster technology-based agbioscience development, the OARDC and community stakeholders in Wayne County have worked with the Battelle Technology Partnership Practice to assess the feasibility of establishing an agriculture-oriented research and commercialization park on the OARDC campus site.

Our research concluded that it is possible to develop a viable agbioscience research park in Wayne County. However, in order to do so, the region's efforts must focus on the key ingredients that will help spur economic growth, including developing research anchors, focusing on commercializing research into the marketplace through emerging firms, and nurturing those firms in the region through services and programs such as incubators and accelerators. Focusing resources, mobilizing private and public partnerships, and having patience and a long-term commitment are critical to developing the park.

An agbioscience research park in Wayne County can add real value to the region. The Greater Wayne County's industrial base, research assets, and global trends in agricultural markets would suggest that it would be in the best interest of the county to take advantage of test fields, an arboretum, and existing land by carefully planning and implementing a nontraditional research park. But, to create a research park providing value-added, high-quality research and development jobs rather than another office park, it will be absolutely critical for the region to recognize that this is a long-term proposition that will require a sustained commitment. It should be anticipated that the research park will grow exponentially over an 8- to 10-year period or longer.

It also should be realized that the agbioscience research park is a unique design. It will seek to attract tenants based on their desire to be in close proximity to OARDC and the other proposed research anchors and to benefit from the services provided to park tenants. To build such a park requires that the project's sponsors be willing to secure public and private investments in the research and development anchors that will be needed to create a research park.

Core Competency Linkages—*The BioHio Research Park would be a facilitator to potential commercialization opportunities from each of the identified core competency platforms and the broader collaboratory opportunities.*

OTHER OARDC PROGRAMS

The OARDC also is funding some comparatively new interdisciplinary programs that are relevant to the core competency and collaboratory platforms.

The Ohio Composting and Manure Management Program

The OCAMM will likely be a valuable contributor to both the Advanced Growing Media Technology Platform and the Environmental Protection and Decontamination Technology Platform. OCAMM's goal is to "research, develop and communicate sustainable strategies for the management of animal manure and nutrient inputs on Ohio farms."[18]

OCAMM is working on strategies such as composting, land application, facility design, and feed management—assessing these technologies and processes for their ability to recycle nutrients, reduce the need for chemical fertilizer and pesticide inputs, improve soil fertility, reduce odor emissions, and improve environmental stewardship. OCAMM program participants include livestock producers, livestock system consultants, equipment manufacturers, trade associations, compost users, and public agencies as well as faculty and staff at OSU. The overall goals of OCAMM are

- To develop, demonstrate, and teach the most economically, ecologically, and environmentally appropriate approaches to animal manure management for both large and small Ohio producers.
- To help Ohio livestock and composting businesses achieve consistent production of high-quality, diverse, stable, accurately labeled, and safe bioproducts that include various levels of animal manure.
- To maintain and build on OSU's regionally, nationally, and internationally recognized capabilities through exemplary teaching, research, demonstration, and outreach activities in composting and livestock manure management.[19]

The OCAMM Program builds upon the existing expertise of OARDC scientists in composting and waste management technologies and practices.

The Ohio Aquaculture Program

Operated from the OARDC Piketon branch station, the Ohio Aquaculture Program is helping to lead diversification of income streams for Ohio farmers through the application of the aquaculture of fish and freshwater shrimp. The OAP works to provide practitioners and potential aquaculturists in Ohio with information on fish culture methods, nutritional requirements, aquacultural system design and management, species selection, and water quality management.[20]

The Piketon center is fielding an increasing volume of inquiries and requests for information in relation to aquaculture. Currently this is, however, still a fledgling industry in Ohio, with its growth being supported by OARDC through

[18] http://www.oardc.ohio-state.edu/ocamm/.
[19] Ibid.
[20] http://southcenters.osu.edu/aqua/.

- Research on appropriate fish species, shrimp species, spawning, aquaculture methods and management
- Educational programs, materials, and seminars aimed at enhancing the efficiency of current aquaculturists in Ohio and providing potential producers with the in-depth knowledge required to make informed production decisions.

While not currently focused on transgenics research, OARDC's growing aquaculture expertise may provide an additional pathway from and to transgenics research and the Food Animal Improvement Technology Platform.

The Center for Advanced Processing and Packaging Studies

CAPPS is a major federal initiative funded by the NSF. The goal of the initiative is "to conduct industrially relevant research directed at developing methods and technologies for the production of safe, marketable, high-quality shelf-stable aseptic and refrigerated extended shelf-life products."[21]

The initiative brings together OSU scientists in agriculture, food science, engineering, and a broad variety of additional disciplines to work on projects that

- Enhance the safety and quality of aseptic and extended shelf-life products
- Characterize emerging, aseptic and extended shelf-life processes
- Assure the integrity and functionality of aseptic and extended shelf-life packaging.[22]

CAPPS is a pragmatic, applied initiative that links university scientists and scientific resources with key industrial players in the food packaging, aseptic processing, and related technology manufacturers. This emerging initiative has already attracted the involvement and formal membership of some of the major corporations active within the industry, including Coca-Cola, ConAgra Foods, Gerber, Kraft Foods, Procter & Gamble, Abbott Labs, and Tetra Pak.

Some of the research approaches being taken under the CAPPS initiative include those in sterilization and pasteurization using pulsed electric fields, ohmic heating, and high pressure methodologies. The CAPPS initiative is seen by the Battelle research team to be a model program and the core of the Food Safety Technology Platform.

The Center for Innovative Food Technology

CIFT is an initiative funded by the USDA. Like CAPPS, CIFT is an interdisciplinary program aimed at providing formal links between scientists and academic researchers in the university community and industry practitioners—and through these links it aims to provide applied solutions to problems and challenges in topics ranging from food safety and quality to functional foods and "foods of the future."

As a core goal, CIFT is working to provide U.S. and Ohio food processors with technical solutions that will give them a competitive edge in one of the largest industry sectors. It also provides training and education services and information services targeted at small business development within the sector. CIFT is, therefore, a center with direct relevance to the further development of many of the core competency platforms and the broad R&D Collaboratories.

[21] http://www-fst.ag.ohio-state.edu/CAPPS/mission.html.
[22] http://www-fst.ag.ohio-state.edu/CAPPS/objectives.html.

CONCLUSION

The preceding analysis confirms that OARDC has multiple new and emerging initiatives aimed at leveraging life science advances and biotechnology for the benefit of Ohio and Ohioans. Upon review, it is evident that the majority of these new and emerging OARDC initiatives have direct or indirect linkages to the recommended core competency platforms and will serve as important building blocks in developing the proposed Collaboratories.

Conclusion

The analysis undertaken and conclusions drawn in this study, *OARDC's Competitive Positioning Strategy: A Development Path for the Future,* represents the second phase of a three-phase effort. The third phase involved an independent external review and assessment of Battelle's findings regarding OARDC's contribution to Ohio's economy and its capacity to be an economic driver in the future. This external independent review team was comprised of four world-renown experts:

- Dr. Daryl B. Lund, Executive Director, North Central Regional Association of State Agricultural Experiment Station Directors and Professor of Food Engineering, University of Wisconsin-Madison;
- Dr. Clifton A. Baile, Distinguished Professor of Animal Science and Foods and Nutrition, and Georgia Research Alliance Eminent Scholar in Agricultural Biotechnology, University of Georgia-Athens;
- Dr. Neal Van Alfen, Dean of the College of Agriculture and Environmental Sciences, Professor of Plant Pathology, University of California, Davis; and,
- Dr. William R. Woodson, Director Indiana Agricultural Experiment Station, Professor of Molecular Biology, Purdue University.

The Assessment Team concluded that "In our opinion, it is not a stretch of the imagination that farming would not be nearly so attractive or profitable in Ohio if there were no agricultural experiment station…If it is assumed that the state's investment in OARDC (approximately $35M annually) went entirely to support agricultural production, then the state is investing 0.07% of the value of the agriculture sector…The challenge for OARDC leadership is to determine the appropriate balance between the broad research needs of the agricultural and environmental communities of Ohio and new investments in the core disciplinary competencies in research that have been identified in this study…The team believes that OARDC is well positioned to build upon its key strengths and leverage them for agricultural economic development. The Team supports the conclusion that the key focus must be to ensure that the proper infrastructure and investments are put in place to maximize the economic development potential for the agricultural industry."

This independent review affirms Battelle's findings that the biosciences have been identified as the underlying technology platform for the growth of state and regional economies in the coming decades. The biosciences have been identified as the underlying technology platform for the growth of state and regional economies in the coming decades. States are realizing that their traditional economic bases may undergo significant change and are increasingly embracing the biosciences, in all its forms, as a path to future economic progress. Agbioscience, with its connection to the immense plant and animal gene pool, is increasingly being seen as a key component contributing to current and future bioscience economic development.

This assessment of Ohio's strengths in the agbiosciences, gained through the research and operations of the OARDC, highlights significant agbioscience areas in which The Ohio State University and OARDC show strong core competencies upon which to build. More than 99 percent of the academic agbioscience R&D in Ohio is performed by OSU. Therefore, the agbiosciences present a unique opportunity to generate focused results through the efficient means of funding one institution.

Ohio has quite substantial strengths in all three legs of the "bioscience stool"—namely, human biosciences (at multiple academic medical centers) and animal and plant biosciences (at OSU). To a large degree, we anticipate that multidisciplinary approaches to agbioscience and bioscience issues in general will favor those states that can be a player in each of the bioscience fields. Ohio has this opportunity.

Significant agbioscience core competency platforms exist at OARDC and OSU. These strength areas are diverse and include plant sciences, animal sciences, agricultural and food processing technologies, and environmental sciences. Through further investment in sustaining and building upon OARDC's core agbioscience competencies, it is anticipated that significant agbioscience cluster growth can occur in Ohio.

The opportunities are such, however, that an even broader agbioscience investment approach could be adopted in Ohio. As envisioned, this would involve building a formal OARDC Ohio Agbioscience Initiative, with three OARDC/Industry Collaboratories and associated R&D programs, focused on building Ohio's 21st century agbioscience position. The three Collaboratories would focus specifically on bringing OARDC's agbioscience research expertise together with commercial agbioscience industry to work on pragmatic, applied projects to develop Ohio's

- Advanced Food Economy
- Biobased Economy
- Environmental Economy.

Building upon OARDC's strengths and gaining momentum for economic development in agbioscience for Ohio should be considered high priorities for the State of Ohio, given the likely preeminent importance of bioscience in general to a knowledge-driven, 21st century economy.

Appendix A: Detailed Agbioscience Industry SIC Definition

Agriculture-Bioscience Industry			
Industry Subsector	**SIC**	**Industry Subsector**	**SIC**
Agricultural Services		**Agricultural Processing**	
Soil preparation services	0711	Wet corn milling	2046
Crop protecting services	0721-03	Cottonseed oil mills	2074
Crop cultivating services	0721-04	Soybean oil mills	2075
Crop planting and protection, nec	0721-99	Vegetable oil mills, nec	2076
Livestock reproduction services	0751-04	Animal and marine fats and oils	2077
Vaccinating services, livestock	0751-9905	Edible fats and oils	2079
Animal breeding services	0752-01	Malt	2083
Food Processing		Organic fibers, noncellulosic	2824
Meat packing plants	2011	**Drugs and Pharmaceuticals**	
Sausages and other prepared meats	2013	Medicinals and botanicals	2833
Poultry slaughtering and processing	2015	Pharmaceutical preparations	2834
Creamery butter	2021	Diagnostic substances	2835
Cheese; natural and processed	2022	Biological products except diagnostic	2836
Dry, condensed and evaporated dairy products	2023	**Organic and Agricultural Chemicals**	
Ice cream and frozen deserts	2024	Industrial organic chemicals, nec	2869
Fluid milk	2026	Nitrogenous fertilizers	2873
Canned specialties	2032	Phosphatic fertilizers	2874
Canned fruits and specialties	2033	Fertilizers mixing only	2875
Dried and dehydrated fruits, vegetables and soup mixes	2034	Agricultural chemicals, non-fertilizer	2879
Pickles, sauces, and salad dressings	2035	**Agricultural Machinery and Equipment**	
Frozen fruits and vegetables	2037	Farm machinery and equipment	3523
Frozen specialties, nec	2038	Lawn and garden equipment	3524
Flour and other grain mill products	2041	Food products machinery	3556
Cereal breakfast foods	2042	**Biological Research and Testing**	
Rice milling	2044	Medical laboratories	8071
Prepared flour mixes and doughs	2045	Biological research	8731-0100
Dog and cat food	2047	Biotechnical research, commercial	8731-0102
Prepared feeds, nec	2048	Medical research commercial	8731-9902
Bread, cake, and related products	2051	Noncommercial biological research organization	8733-01
Cookies and crackers	2052	**Agricultural Research and Testing**	
Frozen bakery products, except bread	2053	Agricultural research	8731-0101
Candy and other confectionery products	2064	Food research	8731-0103
Chocolate and cocoa products	2066	Pollution testing	8734-03
Chewing gum	2067	Food testing service	8734-9903
Salted and roasted nuts and seeds	2068	Seed testing laboratory	8734-9908
Malt beverages	2082	Soil analysis	8734-9909
Wines, brandy, and brandy spirits	2084	Veterinary testing	8734-9910
Distilled and blended liquors	2085	Water testing laboratory	8734-9911
Bottled and canned soft drinks	2086		
Flavoring extracts and syrups, nec	2087		
Potato chips and similar snacks	2096		
Manufactured ice	2097		
Macaroni and spaghetti	2098		
Food preparations, nec	2099		

SIC = Standard Industrial Classification nec = not elsewhere classified.

Appendix B:
Detailed Ohio Agbioscience Subsector Performance

Table B-1: Ohio and National Agbioscience Subsector Comparison, 1998 to 2003

	Total Life Sciences	Agricultural Services	Food Processing	Agricultural Processing	Drugs & Pharma-ceuticals	Organic & Agricultural Chemicals	Agricultural Machinery Equipment	Biological Research & Testing	Agricultural Research & Testing
Ohio									
Establishments									
1998	2,241	235	1,034	29	101	131	123	528	60
2003	2,839	273	1,142	37	149	143	226	796	73
Change	598	38	108	8	48	12	103	268	13
% Change	26.7%	16.2%	10.4%	27.6%	47.5%	9.2%	83.7%	50.8%	21.7%
Employment									
1998	90,062	1,421	59,996	1,608	6,335	7,119	6,320	5,999	1,264
2003	92,303	828	52,750	6,220	7,352	6,362	6,579	10,492	1,720
Change	2,241	(593)	(7,246)	4,612	1,017	(757)	259	4,493	456
% Change	2.5%	-41.7%	-12.1%	286.8%	16.1%	-10.6%	4.1%	74.9%	36.1%
Employees per Firm									
1998	38	6	58	55	63	54	51	11	21
2003	33	3	46	168	49	44	29	13	24
Location Quotient									
1998	0.81	0.94	0.93	0.45	0.43	0.98	1.07	0.53	0.74
2003	0.80	0.53	0.83	1.96	0.42	0.99	1.13	0.68	1.09
Change	-0.01	-0.40	-0.09	1.50	-0.01	0.01	0.06	0.15	0.35
Share of Private Sector Employment									
1998	1.763%	0.028%	1.175%	0.031%	0.124%	0.139%	0.124%	0.117%	0.025%
2003	1.654%	0.015%	0.945%	0.111%	0.132%	0.114%	0.118%	0.188%	0.031%
Share of Life Science Employment									
1998	na	0.055%	2.343%	0.063%	0.247%	0.278%	0.247%	0.234%	0.049%
2003	na	0.030%	1.916%	0.226%	0.267%	0.231%	0.239%	0.381%	0.062%
United States									
Establishments									
1998	68,115	8,317	31,456	980	4,088	3,017	4,074	14,077	2,106
2003	83,740	9,522	35,326	1,094	5,873	3,453	5,150	20,917	2,405
Change	15,625	1,205	3,870	114	1,785	436	1,076	6,840	299
% Change	22.9%	14.5%	12.3%	11.6%	43.7%	14.5%	26.4%	48.6%	14.2%
Employment									
1998	2,560,422	34,884	1,495,123	82,068	343,197	168,045	136,428	261,447	39,230
2003	2,753,732	37,091	1,517,148	76,170	419,741	154,578	139,158	372,114	37,732
Change	193,310	2,207	22,025	(5,898)	76,544	(13,467)	2,730	110,667	(1,498)
% Change	7.5%	6.3%	1.5%	-7.2%	22.3%	-8.0%	2.0%	42.3%	-3.8%
Employees per Frim									
1998	38	4	48	84	84	56	33	19	19
2003	33	4	43	70	71	45	27	18	16
Share of Private Sector Employment									
1998	2.174%	0.030%	1.269%	0.070%	0.291%	0.143%	0.116%	0.222%	0.033%
2003	2.060%	0.028%	1.135%	0.057%	0.314%	0.116%	0.104%	0.278%	0.028%
Share of Life Science Employment									
1998	na	1.362%	58.394%	3.205%	13.404%	6.563%	5.328%	10.211%	1.532%
2003	na	1.347%	55.094%	2.766%	15.243%	5.613%	5.053%	13.513%	1.370%